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PASSIVE NOSETIP TECHNOLOGY (PANT) PROGRAM

VOLUME XVII. COMPUTER USER'S MANUAL: EROSION SHAPE (EROS) COMPUTER CODE

ACUREX CORPORATION

PREPARED FOR

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INTERIM REPORT
PASSIVE NOSETIP TECHNOLOGY
(PANT) PROGRAM

Volume XVII. Computer User's Manual: Erosion Shape (EROS) Computer Code

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D. Rafinejad
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Letter on file

A

FOREWORD

This document is Volume XVII of the Interim Report series for the Passive Nosetip Technology (PANT) program. A summary of the documents in this series prepared to date is as follows:

Volume I - Program Overview (U)

Volume II - Environment and Material Response Procedures for Nosetip Design (U)

Volume III - Surface Roughness Data

- Part I - Experimental Data
- Part II - Roughness Augmented Heating Data Correlation and Analysis (U)
- Part III - Boundary Layer Transition Data Correlation and Analysis (U)

Volume IV - Heat Transfer and Pressure Distributions on Ablated Shapes

- Part I - Experimental Data
- Part II - Data Correlation

Volume V - Definition of Shape Change Phenomenology from Low Temperature Ablator Experiments

- Part I - Experimental Data, Series C (Preliminary Test Series)
- Part II - Experimental Data, Series D (Final Test Series)
- Part III - Shape Change Data Correlation and Analysis

Volume VI - Graphite Ablation Data Correlation and Analysis (U)

Volume VII - Computer User's Manual, Steady-State Analysis of Ablating Nosetips (SAANT) Program

Volume VIII - Computer User's Manual, Passive Graphite Ablating Nosetip (PAGAN) Program

Volume IX - Unsteady Flow on Ablated Nosetip Shapes - PANT Series G Test and Analysis Report

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Volume X	- Summary of Experimental and Analytical Results
Volume XI	- Analysis and Review of the ABRES Combustion Test Facility for High Pressure Hyperthermal Reentry Nosetip Systems Tests
Volume XII	- Nosetip Transition and Shape Change Tests in the AFFDL 50 MW RENT Arc - Data Report
Volume XIII	- An Experimental Study to Evaluate Heat Transfer Rates to Scalloped Surfaces - Data Report
Volume XIV	- An Experimental Study to Evaluate the Irregular Nosetip Shape Regime - Data Report
Volume XV	- Roughness Induced Transition Experiments - Data Report
Volume XVI	- Investigation of Erosion Mechanics on Reentry Materials (U)
Volume XVII	- Computer User's Manual, Erosion Shape (EROS) Computer Program
Volume XVIII	- Nosetip Analyses Using the EROS Computer Program

This report was prepared by Aerotherm Division/Acurex Corporation under Contract F04701-74-C-0069. Volumes I through IX covered PANT activities from April 1971 through April 1973. Volumes X through XV represent contract efforts from May 1973 to December 1974. Volume X summarizes the respective test programs and describes improvements in nosetip analysis capabilities. Volume XI presents an evaluation of the ABRES test facility in terms of performing thermostructural and reentry flight simulation testing. Volumes XII through XV are data reports which summarize the experiments performed for the purpose of defining the irregular flight regime. The analysis of these data are presented in Volume X. Volumes XVI through XVIII describe the background, development, and check out of the PANT EROsion Shape (EROS) computer code. These volumes document efforts performed under supplementary agreements to the Minuteman Natural Hazards Assessment Program (Contract F04701-74-C-0069) between April 1974 and March 1975.

This work was administered under the direction of the Space and Missile Systems Organization with Lieutenant A. T. Hopkins and Lieutenant E. G. Taylor as Project Officers with Mr. W. Portenier and Dr. R. L. Baker of the Aerospace Corporation serving as principal technical monitors. Dr. Dariush Rafinejad was principal Aerotherm investigator for the work described in this volume.

This technical report has been reviewed and is approved.

E G Taylor

E. G. Taylor, Lt., USAF
Project Officer
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ABSTRACT

A computer program is developed to numerically model the in-depth transient response and shape history of an ablating nosetip subjected to a reentry environment. The generality of the input also allows the user to conveniently analyze the boundary layer, shape change and in-depth response of many materials in a variety of test facilities. The computer code is capable of handling nosetips of shell or plug geometries. The boundary layer and heat transfer distribution are modeled for a variety of environments including hydrometer erosion. In addition, inviscid flow and heat transfer distributions for many types of blunt bodies in hypersonic flow can be readily calculated.

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LIST OF SYMBOLS

B'	normalized ablation rate defined as $\dot{m}/\rho_e u_e C_M$	(---)
C_D	drag coefficient	(---)
C_H	Stanton number for heat transfer (corrected for "blowing" if necessary	(---)
$C_{H,O}$	Stanton number for heat transfer not corrected for blowing or stagnation point Stanton number	(---)
C_M	Stanton number for mass transfer	(---)
C_p	specific heat at constant pressure or pressure coefficient	(Btu/lb°F) or (---)
D	diameter at start of aft cone	(ft)
d	minimum mesh size	(ft)
d_p	hydrometeor particle diameter	(ft)
F	radiation view factor	(---)
F_K	factor in Equation (2-27)	(---)
F_L	ratio of local laminar heat transfer coefficient to stagnation point coefficient	(---)
F_T	ratio of local composite turbulent heat transfer coefficient to stagnation point coefficient	(---)
G	erosion mass loss parameter	(---)
H	boundary layer shape factor	(---)
H_D	dissociation energy	(Btu/lb)

LIST OF SYMBOLS (Continued)

H_O	total enthalpy	(Btu/lb)
H_r	recovery enthalpy	(Btu/lb)
h	enthalpy	(Btu/lb)
h_c	material enthalpy	(Btu/lb)
h_i^{Tw}	enthalpy of species i at temperature Tw	(Btu/lb)
h_s	sensible enthalpy	(Btu/lb)
h_w	enthalpy of gases adjacent to the wall	(Btu/lb)
$\bar{h}$	Eckert reference enthalpy	(Btu/lb)
J	internal conduction node index (X-direction)	(---)
K	internal conduction node index (η-direction)	(---)
K_i	mass fraction of species i	(---)
K_L	rough wall laminar heating augmentation factor	(---)
K_T	rough wall turbulent heating augmentation factor	(---)
$K_{T,C}$	rough wall composite heating augmentation factor	(---)
K_1	material coefficient in Equation (2-46)	(in -psia$^{.77}$)
k	thermal conductivity or roughness height	(Btu/ft-sec°F) or (ft)

LIST OF SYMBOLS (Continued)

k_c	crater roughness height	(ft)
k_i	intrinsic roughness of material in laminar flow	(ft)
k_t	effective sand grain roughness height	(ft)
L	internal conduction node index (ϕ-direction)	(---)
Le	Lewis number	(---)
M	Mach number	(---)
$\dot{m}$	net mass ablation rate per unit area	(lb/ft^2-sec)
$\dot{m}_e$	erosion mass removal rate per unit area	(lb/ft^2-sec)
$\dot{m}_{in}$	incoming hydrometer particle mass flux	(lb/ft^2-sec)
m_p	individual hydrometer particle mass	(lb)
$\dot{m}_{tc}$	thermochemical mass ablation rate per unit area	(lb/ft^2-sec)
Pr	Prandtl number	(---)
p	pressure	(atm)
$\bar{p}$	p/p_o	(---)
q	heat flux	(Btu/ft^2sec)
q_{chem}	heat flux resulting from chemical energy	(Btu/ft^2sec)
q_{cond}	heat flux conducted into solid material at surface	(Btu/ft^2sec)
$q_{rad\ in}$	heat flux radiated to surface	(Btu/ft^2sec)

$q_{rad\ out}$	heat flux radiated away from surface	(Btu/ft^{2}sec)
q_{sen}	sensible convective heat flux	(Btu/ft^{2}sec)
R_{eff}	effective nose radius	(ft)
R_N	geometric body radius of curvature at stagnation point	(ft)
Re	unit Reynolds number	(ft^{-1})
Re_k	roughness Reynolds number	(---)
Re_θ	momentum thickness Reynolds number	(---)
$\overline{Re}_\theta$	composite momentum thickness Reynolds number based on reference conditions	(---)
$\overline{RKL}$	roughness - laminar heating parameter	(---)
$\overline{RKT}$	roughness - turbulent heating parameter	(---)
R_L	laminar Reynolds analogy factor	(---)
R_T	turbulent Reynolds analogy factor	(---)
r	radius measured from body axis	(ft)
r_b	internal conduction radius measured from body axis	(ft)
s	streamwise length	(ft)
S	transformed Z-coordinate, = Z/δ	(---)
$\dot{S}$	normal surface recession rate	(ft/sec)

LIST OF SYMBOLS (Continued)

T	temperature	(°R)
t	time	(sec)
Δt	time step size	(sec)
u	velocity	(ft/sec)
X	length measured from the axis along the internal contour	(ft)
Y	distance measured normal to internal contour or fictitious interface	(ft)
$\bar{y}$	radial location of streamline	(ft)
z	axial length measured from original stagnation point	(ft)
Z	axial distance measured from the back of the body	(ft)
z_c	axial distance from start of aft cone.	(ft)
z_i^*	modified diffusion driving force (see Reference 21, page 44 for definition)	(---)

Greek Symbols

α	material thermal diffusivity	(ft^2/sec)
α_w	absorptivity of wall	(---)
β	angle local tangent to the inner contour makes with the body axis	(deg)
β_o	stagnation point velocity gradient defined as $du_e/ds\Big\|_{s\to o}$	(sec^{-1})
$\tilde{\beta}$	velocity gradient parameter	(---)
γ	specific heat ratio or plug shank inclination angle with the axis	(---), (deg)
Δ	distance from the inner contour to the nosetip surface	(ft)

Δ_o	shock standoff distance	(ft)
δ	distance from shank base to fictitious interface	(ft)
δ^*	boundary layer displacement thickness	(ft)
η	transformed Y-coordinate, = Y/Δ	(---)
ε	emissivity	(---)
ε_s	density ratio across shock	(---)
θ	momentum thickness	(ft)
θ_s	shock angle	(deg)
λ	blowing reduction parameter (Equation (2-61))	(---)
Λ	curvature of internal contour	(ft^{-1})
μ	viscosity	(lb/ft-sec)
$\bar{\mu}$	viscosity evaluated at Eckert reference enthalpy	(lb/ft-sec)
ρ	density	(lb/ft^3)
ρ_c	mass of hydrometer particles per unit volume of air	(lb/ft^3)
ρ_m	surface material density	(lb/ft^3)
ρ_p	hydrometer particle density	(lb/ft^3)
$\bar{\rho}$	density evaluated at Eckert reference enthalpy	(lb/ft^3)
σ	Stefan-Boltzmann constant	($Btu/ft^2 sec\,°R^4$)
τ_w	wall shear	(lbf/ft^2)

LIST OF SYMBOLS (Continued)

ϕ	azimuthal angle	(deg)

Subscripts

c	cone condition
e	boundary layer edge condition
i	condition at start of cone or initial condition or integration point index
L	laminar
MN	modified Newtonian
o	stagnation point or total condition or not corrected for blowing
R	rough
s	sensible
SP	stagnation point
STIRRED	modified to account for the effects hydrometer boundary layer stirring
T	turbulent
TP	tangent point
TR or TRANS	transition point or transitional
tc	thermal chemical only

LIST OF SYMBOLS (Concluded)

w	condition at wall
∞	freestream condition

<u>Superscripts</u>

*	sonic point condition
T_i	value calculated at T_i

SECTION 1

INTRODUCTION

The purpose of this document is to provide a description of the modeling techniques and input requirements of the EROsion Shape (EROS) computer code that combines environment modeling techniques developed by Aerotherm primarily under the PANT program (Reference 29) with in-depth transient conduction routines developed at the Aerospace Corporation (Reference 28).

The primary purpose of this code is to numerically model the in-depth transient response and shape history of an ablating nosetip subject to a reentry environment. The code calculates the inviscid flow and heat transfer distribution for many types of blunt bodies in hypersonic flow. In addition, the boundary layer and heat transfer distributions are modeled for a variety of environments including hydrometer erosion. The in-depth thermal response is capable of calculating the three-dimensional temperature field and surface recession of nosetips at angle of attack. However, due to limitations of the environment package to axi-symmetric geometries, the present code is restricted to nosetips at zero angle of attack. A general thermochemistry model, including kinetic effects, is used in the surface energy balance formalation.

The generality of the input allows the user to conveniently analyze the boundary layer, shape change and in-depth response of many materials in a variety of test facilities, including wind tunnel, ballistic range, and arc heater.

A description of the numerical modeling and calculation procedure is given in Section 2. Input requirements and output are described in Section 3 and a sample problem is presented in Section 4.

SECTION 2

NUMERICAL MODELING AND COMPUTATIONAL PROCEDURES

The problem modeled by the computer code is that of determining the instantaneous shape of an ablating axisymmetric nosetip reentering the atmosphere at zero degrees angle of attack, as well as the in-depth heat transfer and temperature rise. The requirement that the flow be parallel to the body centerline reduces the problem to one of axisymmetric flow and recession. The nosetip shape change events are modeled using the cyclic calculation procedure outlined in Figure 2-1.

The five computation elements illustrated in Figure 2-1 are described in the following sections. Section 2.1 covers the inviscid flow solutions; Section 2.2 described the boundary layer heat and mass transfer calculations; Section 2.3 describes the details of the in-depth conduction calculation; Section 2.4 explains the surface ablation calculations; and Section 2.5 describes the body movement.

The computational scheme is stable and accurate only if computational time steps are kept within certain limits. These limits are imposed by in-depth conduction and shape change and are described in Section 2.3 and 2.5, respectively.

2.1 INVISCID FLOW FIELD

The inviscid flow field serves as a boundary condition for the boundary layer solution. The actual boundary layer edge state is determined from the shock shape and the pressure distribution. The following three sections describe the shock shape, pressure distribution, and boundary layer edge state calculations, respectively. A complete description and justification of the inviscid flow field calculation technique is given in Reference 1.

2.1.1 Shock Shape Calculation

The bow shock geometry ahead of an axisymmetric ablated shape is computed by forming a piecewise linear curve with line segment slopes and lengths dependent on body point slopes and spacing. The technique for evaluating respective shock point locations is given in Figure 2-2. The procedure is to step along

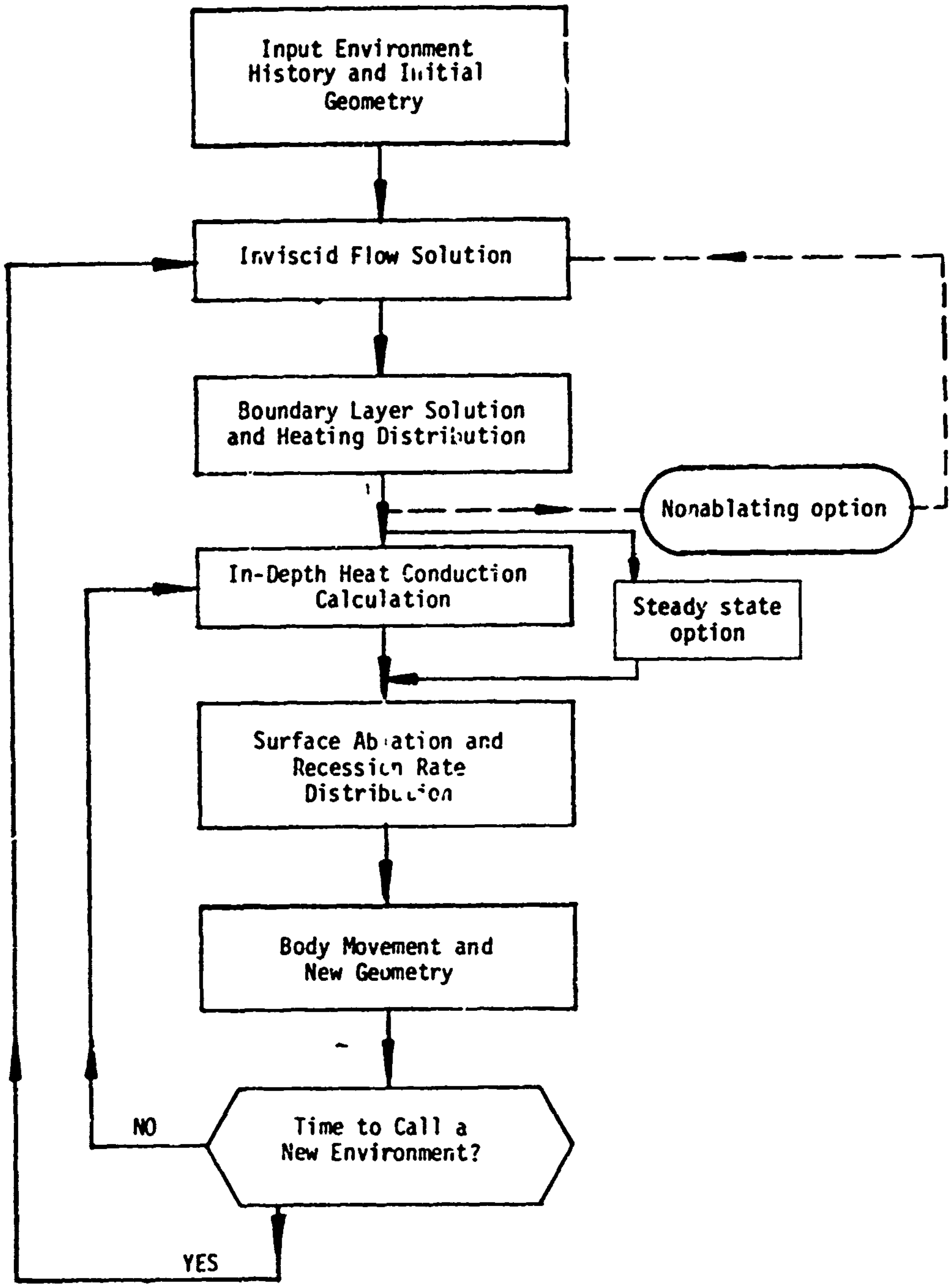
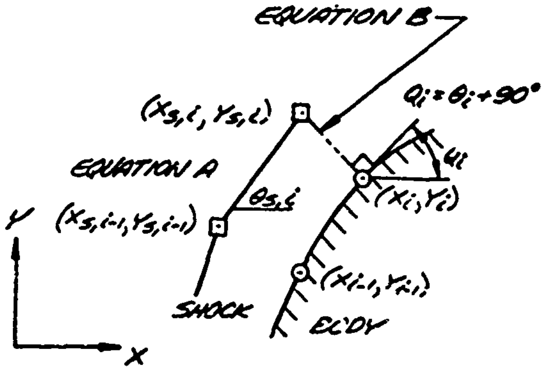


Figure 2-1. Nosetip shape change calculation procedure.

$M \leq 1$



$\theta_{Si} = \theta_{Si}(\theta_i)$
FROM REFERENCE 3
$Q_i = \theta_i + 90°$

SHOCK COORDINATES $(X_{S,i}, Y_{S,i})$ FOUND BY INTERSECTION OF EQUATIONS A AND B

A-10004

EQUATION A

$$Y = Y_{S,i-1} + (X - X_{S,i-1}) \text{ TAN } \theta_{S,i}$$

EQUATION B

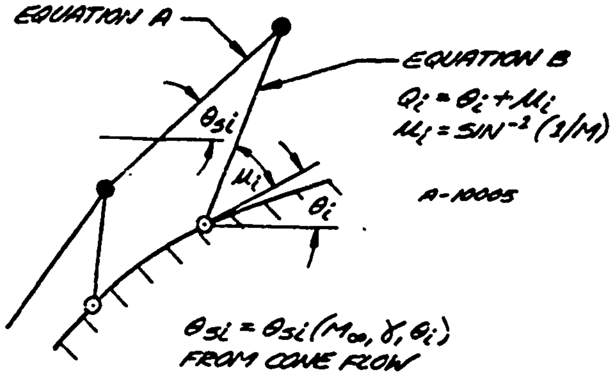
$$Y = Y_i + (X - X_i) \text{ TAN } Q_i$$

COMBINING YIELDS:

$$X_{S,i} = \frac{X_i - (Y_{S,i-1} - X_{S,i-1} \text{ TAN } \theta_{S,i} - Y_i) \text{ TAN } Q_i}{1. + \text{TAN } \theta_{S,i} \text{ TAN } Q_i}$$

$$Y_{Si} = Y_{S,i-1} + (X_{S,i} - X_{S,i-1}) \text{ TAN } \theta_{Si}$$

$M > 1$



$\theta_{Si} = \theta_{Si}(M_\infty, \gamma, \theta_i)$
FROM CONE FLOW CALCULATIONS
$Q_i = \theta_i + SIN^{-2}(1/M)$
AVERAGE OF VALUES BEHIND SHOCK AND AT THE BODY SURFACE.

Figure 2-2. Shock shape evaluation technique.

the shock by computing the next point based on the previous shock point and the surface slope quantities. The following are needed to perform the calculation:

- Body geometry quantities
- Shock standoff distance on the stagnation line
- An expression which relates local surface slope to shock slope.

A correlation based on the results of Reference 30 is used to compute the standoff distance (Δ_o). The correlation, which includes dependencies on stream Mach number, specific heat ratio and body bluntness ratio (i.e., r*/z*) is given by

$$\Delta_o = \left(\frac{\Delta_o}{R_C}\right)_{\text{sphere}} C_R \, r^* \qquad (2\text{-}1)$$

where

$$\left(\frac{\Delta_o}{R_C}\right)_{\text{sphere}} = \left[\left\{\frac{(\gamma-1)\, M_\infty^2 + 2}{4(M_\infty^2-1)} + 1\right\}^{\frac{1}{2K(z)}} - 1\right],$$

r^* is the sonic point ordinate and C_R is a bluntness ratio correction factor which is a function of r^*/z^*.

For subsonic flow in the shock layer the relationship between shock angle and local body angle is obtained from Reference 3 and is given by

$$\theta_{si} = 30° + \frac{\theta_i}{3} + \frac{\theta_i^{\,2}}{270} \qquad (2\text{-}2)$$

where θ_i and θ_{si} are in degrees. The accuracy of this approach is discussed in Reference 1.

For supersonic flow in the shock layer, the shock angle is determined by the tangent cone approximation. In this approach the shock angle is a function of stream Mach number, ratio of specific heats, and body angle.

The procedure is used with all environment options except that for the arc heater. Since nosetip shape change tests in arc heater environments are generally at a relatively low free stream Mach number, it is more accurate to use a normal shock assumption for all inviscid flow calculations.

2.1.2 Pressure Distribution

The pressure distribution calculation is based on regional correlations as indicated in Figure 2-3. Region I is defined as the subsonic portion of the flow forward of the limiting sonic flow characteristic. Region II is the supersonic forebody. Region III is the flow over the aft conic surface of the nosetip and starts at the point where the body slope approaches the cone half angle.

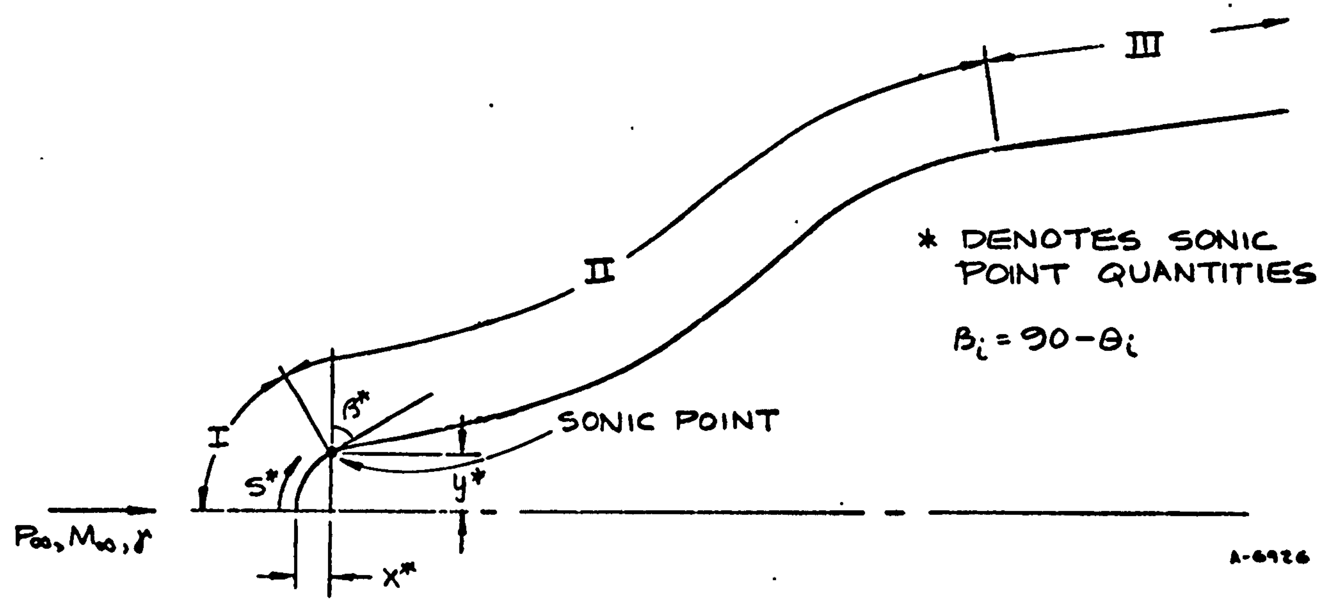


Figure 2-3. Pressure distribution calculation Nomenclature.

A flow chart identifying the various aspects of the pressure distribution calculation is given in Figure 2-4. The procedures used to compute the pressure in the three regions are described in the following subsections.

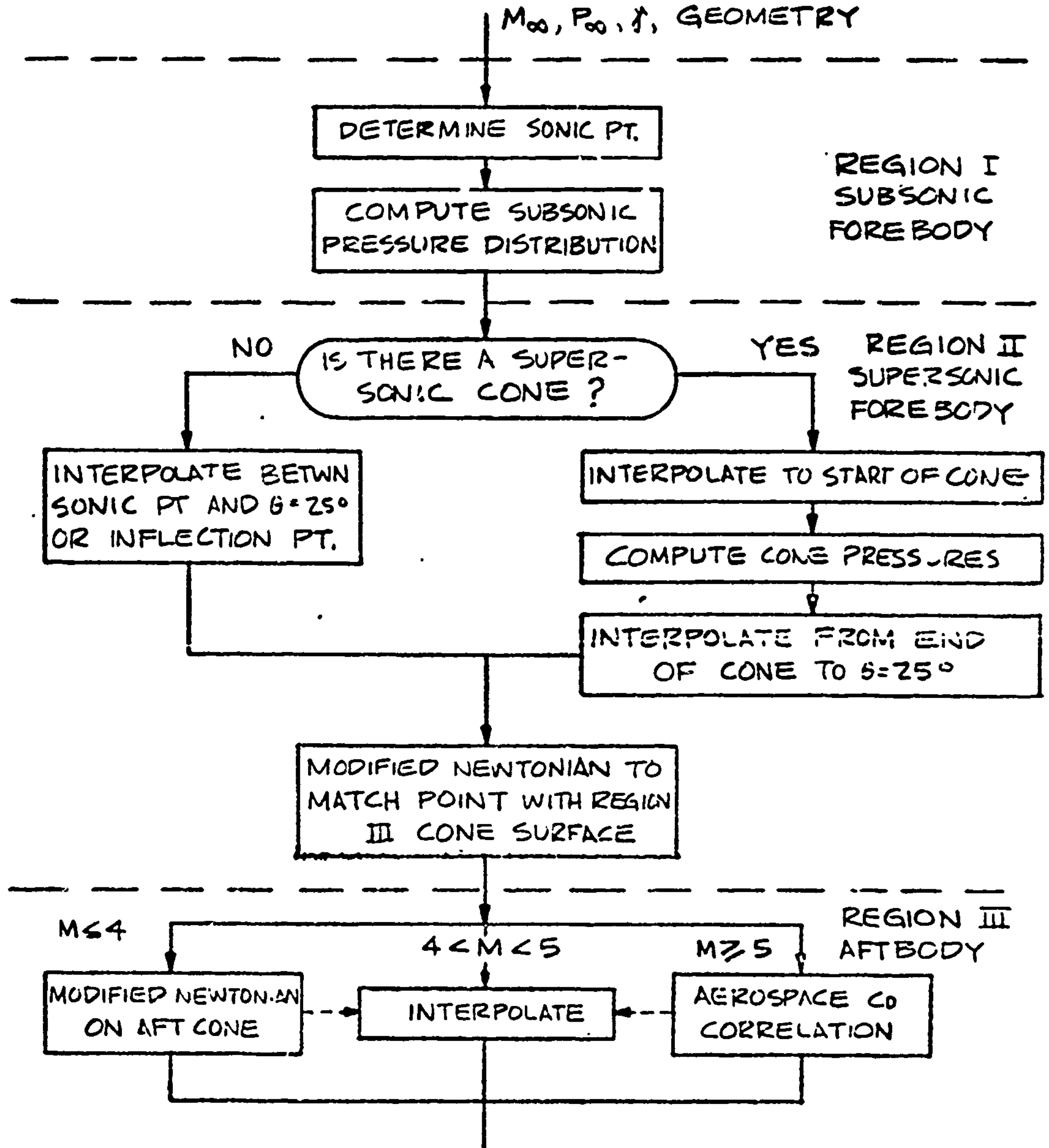


Figure 2-4. Schematic of pressure distribution calculations.

2.1.2.1 Region I, Stagnation Point to Sonic Point

The correlation of Reference 4 as improved in Reference 5 is used in this region to more realistically represent the stagnation point velocity gradient and subsonic region pressure distribution on very blunt bodies. In addition, the correlation was extended to include low free stream Mach numbers. The correlation is an empirical extension and synthesis of the modified Newtonian correlation, valid for spheres, but including a correlation for flat faced cylinders. It is expressed as follows:

$$\bar{p} = \bar{p}_{MN} - (1 - \bar{p}_{FD}) \left[\frac{\bar{p}_{MN} - \bar{p}^*}{1 - \bar{p}^*}\right] + \left(1 - \frac{R_N}{R_{MAX}}\right)$$
$$\left\{(1 - s/s^*)(1 - \bar{p}_\infty)\cos^2\theta + \frac{1}{2}\frac{s}{s^*}\left[\bar{p}_{FD} - 1 + s/s^*(1 - \bar{p}_\infty)\cos^2\theta\right.\right.$$
$$\left.\left. + (1 - \bar{p}_{FD})\left(\frac{\bar{p}_{MN} - \bar{p}^*}{1 - \bar{p}^*}\right)\right]\right\} \tag{2-3}$$

where

$\bar{p} = p/p_o$

p_o = stagnation point pressure

R_N = stagnation point radius of curvature

R_{MAX} = max (R_N, R^*)

R^* = distance from sonic point to body axis, measured normal to the surface at the sonic point

s = surface wetted length from stagnation point

θ = angle local tangent makes with body axis

$*$ = sonic point

and

$$\bar{p}_\infty = p_\infty/p_o \tag{2-4}$$

$$\bar{p}_{MN} = \bar{p}_\infty + (1 - \bar{p}_\infty)\sin^2\theta \tag{2-5}$$

$$\bar{p}^* = \left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma}{\gamma - 1}} \tag{2-6}$$

$$\bar{p}_{FD} = 1 - e^{-\eta}(1 - \bar{p}^*) - \frac{1}{16}\ (s/s^*)^2 - e^{-\eta} \tag{2-7}$$

(flat faced cylinder pressure distribution)

with

$$\eta = 5\sqrt{\ln(s^*/s)} \tag{2-8}$$

The sonic point location is an important parameter in calculating the surface pressure distribution, for it determines the surface length over which the Region I correlation is used in the "subsonic" nose region. The importance of the sonic point reflects the fact that geometry effects downstream of the sonic point have no influence on the subsonic region flow field, and hence, pressure distribution. In the code the sonic point is found using correlations which account for the effects of the following:

- Free stream Mach number (M_∞)
- Ratio of specific heats (γ)
- Nose tip bluntness (r^*/z^*)
- Surface streamline recompression on biconic shapes (β_C^*)

The procedure is to estimate a sonic point location assuming modified Newtonian flow and then correct the location for the effects noted above.

The modified Newtonian sonic point is the first point downstream of the stagnation point ($\beta = 0$), which has an angle (β) greater than the following:

$$\beta_N^* = \text{arc cos}\left(\sqrt{\frac{\bar{p}^* - \bar{p}_\infty}{1 - \bar{p}_\infty}}\right) \tag{2-9}$$

where $\bar{p}_\infty$ and $\bar{p}^*$ are defined in Equations (2-4) and (2-6), respectively, and β^* is defined in Figure 2-3.

The nosetip geometry is then interrogated to determine the following:

- Bluntness ratio at Newtonian sonic point
- The existence of a conic surface with $30° < \beta_C < 60°$ and the conic surface half angle β_C

The bluntness ratio, specific heat ratio, and free stream Mach number are used to obtain a blunt body sonic point from correlations of exact numerical predictions.

$\underline{\gamma = 1.4}$

$\underline{2 < M < 4}$

$$\beta^* = \beta_o^* - 3.495\sqrt{(r^*/z^*)^2 - a^2}$$

$$\beta_o^* = 49.9 + \frac{M - 2.0}{2.0}(50.8 - 49.9)$$

$$a = 2.22 + \frac{M - 2.0}{2.0}(0 - 2.22)$$

$\underline{4 < M < 7}$

$$\beta^* = \beta_o^* - 3.495\sqrt{(r^*/z^*)^2 + b^2}$$

$$\beta_o^* = 50.8 + \frac{M - 4.0}{3.0}(51.3 - 50.8) \qquad (2\text{-}10)$$

$$b = 0.0 + \frac{M - 4.0}{3.0}(2.0 - 0.0)$$

$\underline{M > 7}$

$$\beta^* = \beta_o^* - 3.495\sqrt{(r^*/z^*)^2 + 4}$$

$$\beta_o^* = 51.3$$

$\underline{\gamma \neq 1.4}$

$$\beta^* = \left(\beta_o^*\right)_{1.4} + 1.3\left(\frac{\gamma - 1.4}{0.2}\right)$$

The curves are hyperbolas. The expressions are written in a form to illustrate as clearly as possible their interrelationships.

If a conic surface is formed in the vicinity of the sonic point, the minimum cone half angle for supersonic cone flow is also computed using the following correlations of exact solutions.

$\underline{\gamma = 1.4}$

$$\beta_c^* = 34.6° + 17.9° e^{-0.5739\,(M - 2.0)} \qquad (2\text{-}11)$$

$\underline{\gamma = 1.2}$

$$\beta_c^* = 26.0° + 23.6°e^{-0.5524} (M - 2.0)$$

$\underline{\gamma = 1.1}$ (2-11)

$$\beta_c^* = 19.1 + 28.2°e^{-0.5241} (M - 2.0)$$

For other values of γ, linear interpolation is used.

If the cone half angle (β_c) is greater than β_c^* then the cone is supersonic and the sonic point is at the forward end.

The logic to decide whether the sonic point is controlled by cone flow or blunt body flow is shown in Figure 2-5.

2.1.2.2 Region II, Sonic Point to Match Point with Aft Body Correlations

In the supersonic forebody of the nosetip (Region II) pressure distributions are computed either using the modified Newtonian expression (Equation (2-5)) or, for biconic type configurations, using a conic surface recompression correlation. The cone recompression model is based on sphere/cone and ellipsoid/cone exact solutions performed at various Mach numbers. The streamwise length required to obtain the recompression is given by:

$$\ln\left(\frac{s_R}{R_N}\right) = 4.805(\theta - \theta_o)^2 - 0.22 \qquad (2\text{-}12)$$

where

θ_o = 1.047 radians

s_R = stream length from stagnation point to the end of cone recompression

R_N = geometric stagnation point radius of curvature

Along a conic surface starting at s_i, the recompression pressures are given by a linear function of stream distance; i.e.,

$$\bar{p} = \bar{p}_i + \frac{s - s_i}{s_R - s_i}(\bar{p}_c - \bar{p}_i) \quad \text{for } s_i < s < s_R \qquad (2\text{-}13)$$

$$\bar{p} = \bar{p}_c \quad \text{for } s > s_R$$

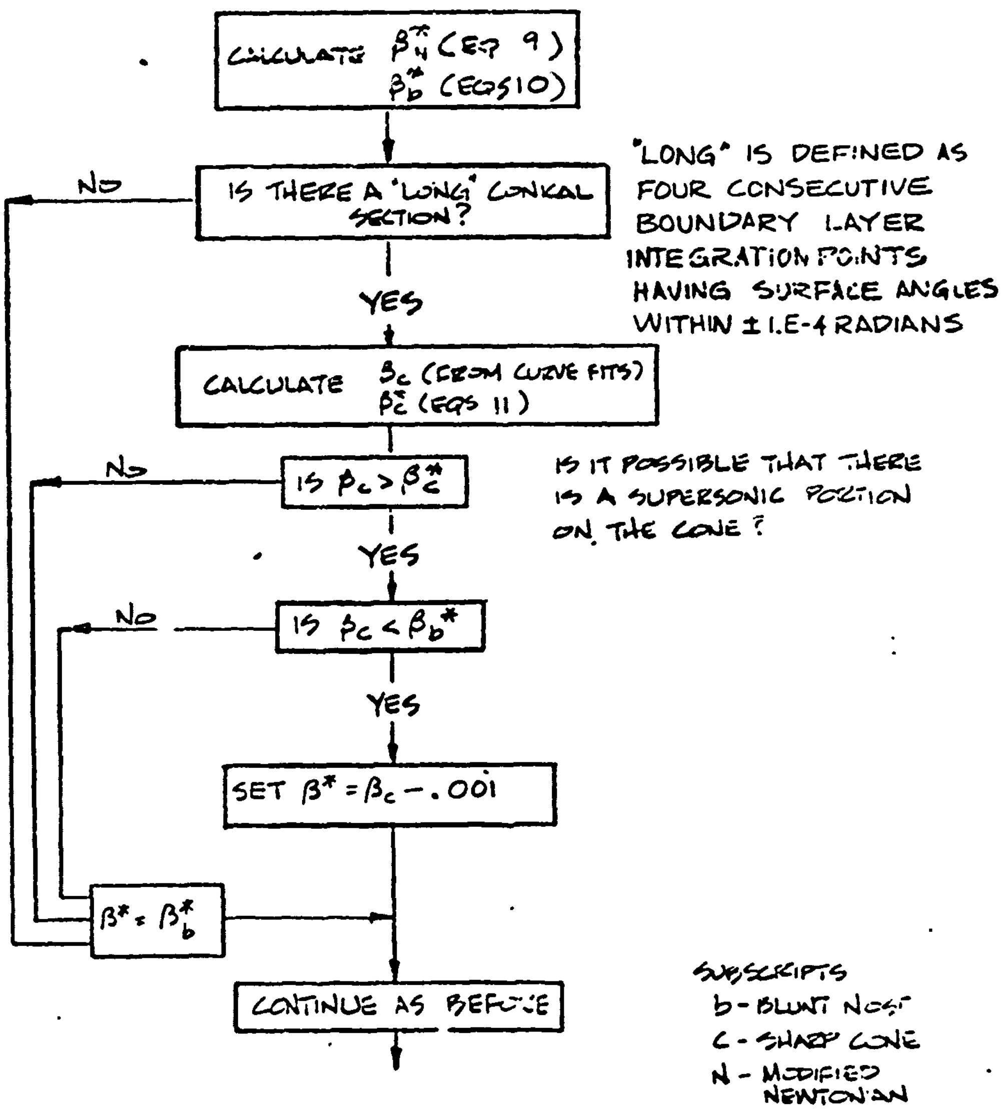


Figure 2-5. Flow chart of logic to determine nosetip sonic point location (subroutine RUNLP).

where

$\bar{p}_c = p_c/p_o$ = sharp cone pressure ratio

$\bar{p}_i = p/p_o$ = pressure ratio at start of cone, s_i

The pressure distribution computation in Region II of the nosetip must also blend together the results from the several correlations, including the following:

- Region I subsonic flow correlation
- Region II conic surface recompression, if any
- Region III C_D correlation, Prandtl-Meyer flow or modified Newtonian (see Section 2.1.2.3)

The smoothing is performed using a weighted average between an incremental modified Newtonian expression and a linear decay expression. For smoothing in the region $\theta_{initial} > \theta > \theta_{final}$

$$\bar{p} = \bar{p}_i + \underbrace{(1 - \alpha) \int_{\theta_i}^{\theta} \frac{d\bar{p}_{MN}}{d\theta}\, d\theta}_{\substack{\text{incremental}\\ \text{modified}\\ \text{Newtonian}}} + \alpha \underbrace{\left(\frac{\theta - \theta_i}{\theta_f - \theta_i}\right)(\bar{p}_f - \bar{p}_i)}_{\substack{\text{linear interpolation}\\ \text{between end of merging}\\ \text{region and sonic point}}} \tag{2-14}$$

where α is the weighting function. Taking a linear weighting,

$$\alpha = \frac{\theta - \theta_i}{\theta_f - \theta_i} \tag{2-15}$$

gives

$$\bar{p} = \bar{p} + \frac{\theta_f - \theta}{\theta_f - \theta_i} (1 - \bar{p}_\infty)(\sin^2\theta - \sin^2\theta_i)$$

$$+ \left(\frac{\theta - \theta_i}{\theta_f - \theta_i}\right)^2 (\bar{p}_f - \bar{p}_i) \tag{2-16}$$

In a typical case, the smoothing expression might be used between the sonic point and the start of a forecone surface and between the end of the forecone and the match point with the Region III correlations. In the case where concave shapes develop as in the sketch below, smoothing is performed between the sonic point and the inflection point in the shape. Downstream of the inflection point, the modified Newtonian relation (Equation (2-5)) is used.

2.1.2.3 Region III - Aft Body

The correlation for aft cone pressures is one developed at Aerospace Corporation (Reference 6). It has the form

$$\frac{C_p}{\theta_c^2} = f_n\left(\frac{z_c}{D}\ \frac{\theta_c^2}{\sqrt{C_D}}\ ,\ \theta_c\right) \tag{2-17}$$

where

θ_c = cone half angle

z_c = axial distance from the start of the aft cone

D = diameter at start of aft cone

C_D = drag coefficient of the forebody

$C_p = (p - p_\infty)/(1/2)\rho_\infty u_\infty^2$

The function f_n is determined by a series of polynomial curve fits of exact numerical solution for cones of varying bluntness, with cone half angle as a parameter. The curves asymptotically approach the sharp cone pressure level.

The transition between Regions II and III is effected at the point where the pressure distribution curves for the two regions intersect. That point is determined iteratively since C_D is a function of its location.

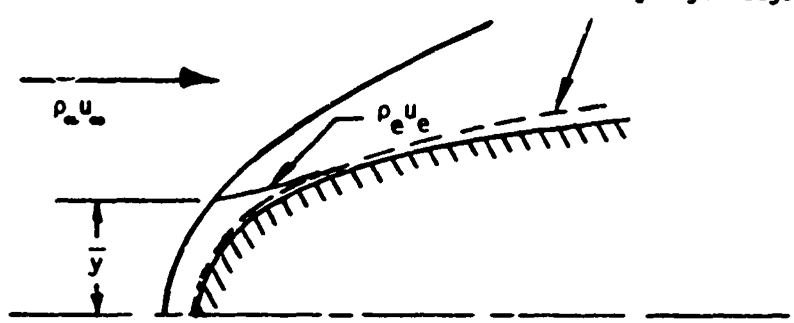
The calculation procedures used in Region III (aft of shoulder) are based on hypersonic considerations. They are used for $M_\infty \geq 5$. To better model the flow for $M_\infty \leq 4$, the modified Newtonian calculation procedure for Region II is extended to Region III. For $4 < M_\infty < 5$, linear interpolation is used between $M_\infty = 4$ and $M_\infty = 5$ predictions.

Alternate procedures are used for cylindrical afterbodies.

2.2.3 <u>Boundary Layer Edge State</u>

The actual boundary layer edge thermodynamic state is determined by a look-up on pressure and entropy in a real gas Mollier air table. Pressure is known from the inviscid flow solution, and entropy is calculated from considerations

of bow shock shape and boundary layer mass flux. The sketch shown on the following page illustrates the path of a streamline passing through the shock layer. At the point where the streamline, originating at $\bar{y}$, enters the boundary layer, the mass flux can be expressed as follows:



For the laminar boundary layer

$$\rho_\infty u_\infty \bar{y}_L^2 = 4.52\, r\mu_e \mathrm{Re}_{\theta_L} \tag{2-18}$$

For the composite model of the turbulent boundary layer, which is described in Section 2.2.2, the free stream location of the boundary layer edge streamline is computed from

$$\rho_\infty u_\infty \bar{y}_T^2 = \left(\frac{100 + 2\overline{\mathrm{Re}}_\theta}{100 + \overline{\mathrm{Re}}_\theta}\right)^2 4.52 r\mu_e \mathrm{Re}_{\theta_T} \tag{2-19}$$

The turbulent Reynolds number, Re_{θ_T}, is computed using a roughness augmented momentum thickness. This expression for $\bar{y}_T$ passes smoothly from the laminar value at $\overline{\mathrm{Re}}_\theta = 0$ to the previously used expression for turbulent flow at large $\overline{\mathrm{Re}}_\theta$.

The entropy used to compute the edge conditions when the streamline enters the boundary layer is the entropy existing at the radial coordinate $\bar{y}_L$ or $\bar{y}_T$ just behind the shock. This entropy is evaluated from the free stream conditions, using oblique shock relations (see Reference 6).

The boundary layer edge velocity over most of the body is computed from energy conservation along an effective inviscid flow stream tube as follows.

$$u_e = \sqrt{2(H_o - h_e)} \tag{2-20}$$

Since the boundary layer edge state is determined accounting for entropy swallowing, the edge velocity also is affected. This is the only mechanism by which swallowing influences the boundary layer solution.

In the vicinity of the stagnation point the velocity is assumed to be linear for p_e/p_{t_2} = 1.0 to 0.999. The velocity at the 0.999 point is calculated accounting for entropy swallowing using a first guess obtained by assuming normal shock entropy. Therefore, the velocity gradient, $du_e/ds|_o$, is evaluated directly from the pressure distribution including entropy layer effects.

The edge viscosity is determined from the following correlation taken from Reference 6.

$$\mu = 3.0 \times 10^{-5} \left(\frac{T}{2000}\right)^{1.5} \left(\frac{2198.6}{T + 198.6}\right) \qquad T < 2000°R$$

$$\mu = 1.9 \times 10^{-5} \left(\frac{T}{1000}\right)^{0.7} \qquad T \geq 2000°R \qquad (2\text{-}21)$$

T in °R, μ in lb/ft-sec units

The Prandtl number is assumed constant at 0.7.

2.2 BOUNDARY LAYER HEAT AND MASS TRANSPORT

The boundary layer heat and mass transport events are modeled using a film coefficient approach. The momentum integral equation is solved assuming that zero pressure gradient relations between skin friction and momentum thickness apply in the presence of pressure gradients. Reynolds analogy and compressibility corrections are applied to obtain the nonblown heat transfer coefficient distribution. Effects of blowing are accounted for as a function of local ablation rate, and the mass transfer coefficient is taken as a constant ratio of heat coefficients.

Details of the solution procedure for laminar flow are given in Section 2.2.1. The turbulent solution procedure is discussed in Section 2.2.2. Transition criteria options in the code are given in Section 2.2.3. Techniques used to compute the roughness effects on laminar and turbulent heating are reviewed in Section 2.2.4, and relations used to compute heat transfer in regions of transitional boundary layer flow are discussed in Section 2.2.5. The effects of hydrometer boundary layer stirring are covered in Section 2.2.6.

2.2.1 Laminar Heat Transfer, Smooth Wall

The stagnation point heat transfer coefficient calculation is discussed in Section 2.2.1.1, and the laminar distribution evaluation technique is described in Section 2.2.1.2.

2.2.1.1 Stagnation Point Heat Transfer Coefficient

At high altitude or low Reynolds number conditions, the energy flux to the surface is limited by the total energy content of the free stream. The corresponding heat transfer coefficient is, therefore,

$$q_{limit} = \rho_\infty u_\infty H_o \tag{2-22}$$

$$\rho_e u_e C_{H,O}\Big|_{limit} = \rho_\infty u_\infty$$

For other conditions, the stagnation point heat transfer coefficient is computed using the relation of Fay and Riddell (Reference 7) with Pr = 0.7.

$$\rho_e u_e C_{H,O} = 0.944(\rho_o \mu_o \beta_o)^{0.5}\left(\frac{\rho_w \mu_w}{\rho_o \mu_o}\right)^{0.1}\left[1.0 + (Le^{0.52} - 1.0)\frac{H_D}{H_o}\right] \tag{2-23}$$

where, as suggested in Reference 8,

$$H_D/H_o = \begin{cases} 0 & , \quad T_o < 5000°R \\ 1 - 0.308(T_o/H_o), & T_o > 5000°R \end{cases} \tag{2-24}$$

The Lewis number used is the average between the Lewis numbers evaluated at the wall and edge temperatures. These are computed from the approximation

$$Le = \begin{cases} 1.2 & , \quad T < 5400°R \\ 1.2 - 5.5 \times 10^{-5}(T - 5400°R), & T > 5400°R \end{cases} \tag{2-25}$$

2.2.1.2 Laminar Heating Distribution

The method of Reference 9 as simplified in Reference 10 is used to obtain the laminar heating distribution. The correlation is expressed as the local heat transfer coefficient divided by the stagnation coefficient, i.e.,

$$F_L = \frac{\rho_e u_e C_{H,L}}{\rho_e u_e C_{H,O}} \tag{2-26}$$

$$F_L = \frac{\frac{p_e}{p_o} u_e r F_k}{\left[\frac{2}{\tilde{\beta}_o} \beta_o \int_o^s (p_e/p_o) u_e r^2 ds\right]^{1/2}} \tag{2-27}$$

where

$$F_K = 1.033 \left(\frac{1 + 0.527\ \tilde{\beta}^{0.686}}{1.116 + 0.411\ \tilde{\beta}^{0.686}}\right) \left[1.10 - 0.1625 \left(\frac{h_e}{H_o}\right) + 0.0625 \left(\frac{h_e}{H_o}\right)^2\right]$$

$$\tilde{\beta} = 2 \left(\frac{h_e}{H_o}\right) \frac{\frac{du_e}{ds}}{\left(\frac{p_e}{p_o}\right) u_e^2 r^2} \int_o^s \left(\frac{p_e}{p_o}\right) u_e r^2 ds$$

The corresponding laminar momentum thickness Reynolds number is obtained by applying Lees transformation to the Blasius incompressible flat-plate skin friction relation. The resulting equation is

$$Re_{\theta_L} = \frac{0.664}{\mu_e r} \left[\frac{\rho_e \mu_e}{p_e/p_o} \int_o^s \left(\frac{p_e}{p_o}\right) u_e r^2 ds\right]^{1/2} \tag{2-28}$$

This Reynolds number and the associated momentum thickness are used to obtain boundary layer thickness parameters for use with transition criteria, transitional heating correlations, and turbulent boundary layer starting conditions.

2.2.2 Turbulent Heat Transfer, Smooth Wall

The compressible boundary layer momentum integral equation is solved to evaluate the fully turbulent heat transfer coefficient distribution. The important assumptions included in the solution are as follows:

- Blowing effects may be decoupled from the boundary layer solution (computes nonblown transfer coefficient).
- Boundary layer shape factor $H = \delta^*/\theta$ is taken as -1.

- A modified Reynolds analogy (explained more completely below) is used to relate heat transfer to skin friction.
- The Crowell incompressible composite skin friction expression (Reference 11) modified for compressibility, is used.

The integral momentum equation may be written as

$$\frac{d}{ds}(\rho_e u_e \theta) = \frac{\tau_w}{u_e} - \rho_e u_e \theta \left[\frac{(1 + H)}{u_e} \frac{du_e}{ds} + \frac{1}{r} \frac{dr}{ds}\right] \tag{2-29}$$

Using properties $(\bar{\rho}, \bar{\mu})$ evaluated at the Eckert reference enthalpy (Reference 12)

$$\bar{h} = 0.5\ h_w + 0.3\ h_e + 0.2\ H_o \tag{2-30}$$

The Crowell composite skin friction expression modified for compressibility is

$$\frac{\tau_w}{u_e} = 0.222 \frac{\mu_e}{\theta} + \lambda \frac{0.0128\ \bar{\rho} u_e}{\overline{Re}_t^{\,1/4}} \tag{2-31}$$

where

$$\lambda = \frac{\overline{Re}_\theta}{100 + \overline{Re}_\theta} \quad \text{and} \quad \overline{Re}_t = \frac{\bar{\rho} u_e \theta}{\bar{\mu}}$$

This expression substituted into the integral momentum equation (which is then integrated) determines $\theta(s)$. Trial calculations for sphere cone geometries were carried out assuming $-1.0 < H < 0.5$. Although $H = 0.5$ is probably most realistic for conditions of interest, the skin friction was found to be relatively insensitive to variations in H. The closest approximation (within 10 percent) between $\theta(0)$ from the composite model and the laminar calculations is obtained for $H = -1$. This value, often assumed because it simplifies the momentum equation, was adopted here.

In using Reynolds analogy to determine the Stanton number from the skin friction, separate factors are used to multiply the laminar and turbulent contributions to the skin friction. The laminar Reynolds analogy factor (taken to be independent of s) is determined from the requirement that the composite model yields the correct heat transfer at the stagnation point, that is,

$$R_L = \frac{\left(\rho_e u_e C_H\right)_{lam,\ s=o}}{0.278\left(\frac{\mu_e}{\theta}\right)_{s=o}} \tag{2-32}$$

The turbulent Reynolds analogy factor, F_T, is currently taken to be unity over the entire body. There is, however, some evidence from turbulent BLIMP solutions that R_T is a function of pressure gradient, being about 0.95 on the nose and about 1.15 on the cone, therefore, the factor, R_T, was chosen to be

$$R_T = 1 \tag{2-33}$$

This is close to the suggestion of Kays' (Reference 14) in which the exponent on the Prandtl number is -0.4. The composite expression for the turbulent heat transfer coefficient becomes

$$\rho_e u_e C_{H,T} = 0.278 \frac{\mu_e}{\theta} R_L + \frac{0.0128\ \bar{\rho} u_e}{\overline{Re}_\theta^{\ 1/4}} \left(R_L (1 - \lambda) + R_T\right) \tag{2-34}$$

The turbulent heating factor is defined as

$$F_T = \frac{\rho_e u_e C_{H,T}}{\rho_e u_e C_{H,O}} \tag{2-35}$$

2.2.3 Transition Criteria

Built into the code are several optional techniques for determining the conditions for boundary layer transition. In summary these are:

- Momentum thickness Reynolds number versus boundary layer edge Mach number.
- Run length Reynolds number versus boundary layer edge Mach number.
- Axial distance from stagnation point versus vehicle altitude.
- Roughwall transition criterion based on momentum thickness and wall cooling ratio.
- Roughwall transition criterion based on displacement thickness and run length.
- Fully turbulent flow from the stagnation point (composite model).

The appropriate boundary layer quantities are computed and compared to critical values input in tabular form by the user. For the two roughwall criteria,

critical values of the appropriate parameters from Reference 15 are built into the code. For the transition correlating parameter involving the momentum thickness, critical values are

$$Re_{\theta}\left[\frac{1}{\left(\frac{B'}{10} + \left(1 + \frac{B'}{4}\right)\frac{\rho_e}{\rho_w}\right)}\frac{k}{\theta}\right]^{0.7} = \begin{Bmatrix} 255, \text{ onset} \\ 215, \text{ location} \end{Bmatrix} \quad (2\text{-}36)$$

For the transition correlating parameter involving the displacement thickness, critical values are

$$Re_k\left(\frac{s}{\delta^*}\right)^{1/3} = \begin{Bmatrix} 2300, \text{ onset} \\ 2000, \text{ location} \end{Bmatrix} \quad (2\text{-}37)$$

where k_i is the intrinsic roughness of the surface appropriate for laminar flow conditions as specified by the user and $Re_k = \rho_e u_e k_i/\mu_e$.

The onset conditions are determined first and, if satisfied, the point of transition is found from the location condition. Equation (2-37) indirectly accounts for the effects of surface temperature on transition through the displacement thickness, δ^*. The displacement thickness is computed from the momentum thickness, θ, and wall to edge temperature ratio, (T_w/T_e) as follows:

$$\theta_{HOT\ WALL} = \theta_{COLD\ WALL}\left[1.104 - 0.348(T_w/T_o)\right]$$

$$(\theta_{COLD\ WALL} \text{ from Eq. (2-28)}) \quad (2\text{-}38)$$

$$\delta^* = \theta_{HOT\ WALL}\left[2.840(T_w/T_e) - 0.640\right]$$

2.2.4 Surface Roughness Effects on Heat Transfer

Correlations from PANT wind tunnel data (Reference 16) are included to account for the effects of roughness on laminar and turbulent heat transfer; in addition, surface roughness modeling accounting for intrinsic roughness, scallop roughness, and crater roughness are included. Roughness effects on laminar and turbulent heating are discussed in Sections 2.2.4.1 and 2.2.4.2 and surface roughness modeling is covered in Section 2.2.4.3.

2.2.4.1 Roughness Effects on Laminar Heating

The effects of roughness on laminar heating are correlated with the parameter

$$\overline{RKL} = Re_2^{0.2} \frac{k_i}{\theta_{HOT\ WALL}} = \left(\frac{\rho_\infty u_\infty R_{eff}}{\mu_o}\right)^{0.2} \frac{k_i}{\theta_{HOT\ WALL}} \quad (2\text{-}39)$$

The effect is accounted for with the multiplicative factor K_L on the smooth wall laminar Stanton number, $C_{H,L}$, where

$$K_L = \frac{C_{H,L,R}}{C_{H,L}} = \begin{Bmatrix} 1.0 & , \overline{RKL} < 50 \\ 1.307\ \ln(\overline{RKL}) + 23.09\ \overline{RKL}^{-0.606} - 6.265, & \overline{RKL} > 50 \end{Bmatrix} \quad (2\text{-}40)$$

The correlation is applied to all laminar flow locations.

2.2.4.2 Roughness Effects on Turbulent Heating

The effects of roughness on turbulent heating are correlated in Reference 16 using the following parameter:

$$\overline{RKT} = Re_k \left(\frac{T_e}{T_w}\right)^{1.3} C_{H,T}^{0.5} = \frac{\rho_e u_e k_t}{\mu_e} \left(\frac{T_e}{T_w}\right)^{1.3} C_{H,T}^{0.5} \quad (2\text{-}41)$$

As with laminar flow, the effect of roughness on turbulent heating is accounted for with a multiplicative factor K_T on the smooth wall Stanton number, $C_{H,T}$. The correlation equation is as follows:

$$K_T = \begin{Bmatrix} 1.0 & , \overline{RKT} \leq 10 \\ \frac{C_{H,T,R}}{C_{H,T}} = \frac{2}{3}\log_{10}(\overline{RKT}) + \frac{1}{3}, & 10 < \overline{RKT} < 10^4 \\ 3.0 & , \overline{RKT} > 10^4 \end{Bmatrix} \quad (2\text{-}42)$$

In the expression for the composite turbulent heat transfer cofficient, the laminar and turbulent contributions are augmented individually, so that on a rough wall,

$$\rho_e u_e C_{H,T,R} = 0.278 \frac{\mu_e}{\theta} R_L K_L + \frac{0.0128\ \bar{\rho} u_e}{\overline{Re}_\theta^{\ 1/4}} \left(R_L K_L (1 - \lambda) + R_T K_T\right) \qquad (2\text{-}43)$$

For the purpose of output a composite turbulent augmentation factor is defined as

$$K_{T,C} = \frac{\rho_e u_e C_{H,T,R}}{\rho_e u_e C_{H,T}} \qquad (2\text{-}44)$$

2.2.4.3 Surface Roughness Modeling

Three types of surface roughness are modeled

- Intrinsic roughness, k_i
- Turbulent or scallop roughness, k_t
- Crater roughness, k_c

Intrinsic roughness (k_i) is that associated with the basic material granularity and is input as a constant for each material. The intrinsic roughness is used in the transition and laminar heating correlations, unless there are particle impacts as described below.

The turbulent roughness (k_t) is the effective sand grain roughness that results from turbulent ablation and is used in the turbulent heating correlations. The roughness height, k_t, is specified in one of two ways. A uniform value of k_t for all turbulent regions may be input by the user; or a value may be obtained by using the scallop dimension correlation from Reference 17. From the correlation, the effective turbulent region scallop depth is computed as follows:

$$k_t = K_1 p_e^{-0.77} \qquad (2\text{-}45)$$

where

k_t = the effective sand grain roughness height suitable for use in Equation (2-41)

K_1 = a material dependent property determined from experimental data and input by the user (a nominal value for graphite is $K_1 = 0.93$ in-psia$^{0.77}$).

p_e = instantaneous local edge pressure

Crater roughness (k_c) results from the impact of hydrometer particles. Presently, the assumption of hemispherical craters is used in conjunction with the mass loss parameter, G, described in Section 2.4.2. Therefore, the crater depth is derived from

$$k_c = \left\{ \frac{G\rho_p}{4\rho_m} \right\}^{1/3} d_p \tag{2-46}$$

where

ρ_p = hydrometer particle density

ρ_m = surface material density

d_p = hydrometer particle diameter

$G = m_e/m_{in}$ = mass loss parameter

k_c = crater depth

Since crater roughness (k_c) occurs over the entire body, the local roughness (either intrinsic (k_i) or turbulent (k_T)) is compared to the crater roughenss (k_c) and the larger is used.

2.2.5 Transitional Boundary Layer Heat Transfer

Transitional heating is computed using a modified version of the correlation of Reference 18. The correlation used is expressed as follows:

$$C_{H,TRANS,R} = C_{H,T,R} - A_{TR}/Re_\theta^n \tag{2-47}$$

The values of A_{TR} and n are computed differently depending on the approach to fully turbulent heating; that is for

$$1 \geq \frac{C_{H,T,R} - C_{H,TRANS,R}}{(C_{H,T,R} - C_{H,L,R})_{TR}} > 0.4$$

then

$$n = 0.85$$

and

$$A_{TR} = \left[Re_\theta^{0.85} \left(C_{H,T,R} - C_{H,L,R} \right) \right]_{TR} \tag{2-48}$$

where TR denotes the values at the point of transition. For

$$0.4 \geq \frac{C_{H,T,R} - C_{H,TRANS,R}}{\left(C_{H,T,R} - C_{H,L,R}\right)_{TR}}$$

then

$$n = 2.0$$

and

$$A_{TR} = \left[Re_\theta^2 \left(C_{H,T,R} - C_{H,TRANS,R}\right)\right]_{0.4} \tag{2-49}$$

where the subscript, 0.4, denotes the point where A_{TR} is reevaluated.

Since the boundary layer is transitional, the momentum thickness Reynolds number (Re_θ) in Equations (2-47) and (2-49) is computed by integrating the reduced form (i.e., H = -1) of the momentum integral equation, Equation (2-29), assuming unity Reynolds analogy factor and using the rough wall Stanton number ($C_{H,TRANS,R}$) from the previous boundary layer integration station, i.e.,

$$Re_{\theta,i} = \frac{\mu_e r Re_\theta\big|_{i-1} + \left(\rho_e u_e r C_{H,TRANS,R}\right)_{i-1}\left(s_i - s_{i-1}\right)}{\mu_e r\big|_i} \tag{2-50}$$

It should be noted that use of rough wall Stanton numbers, $C_{H,L,R}$ and $C_{H,T,R}$, in the transitional heating correlation provides for a reasonable transformation from the laminar to the turbulent roughness effects models described in Section 2.2.4.

2.2.6 Hydrometer Boundary Layer Stirring Effects

Experiments indicate that in regions of laminar flow hydrometer particle impaction and subsequent erosion can cause significant augmentation to the undisturbed laminar heat transfer rate. An option is provided in the code to model this laminar stirring augmentation. The correlation is in terms of the ratio of the disturbed (stirred) heat transfer coefficient to the undisturbed coefficient. The correlation is of the form

$$C_{H_{STIRRED}} = C\left[\frac{\rho_p}{\rho_\infty}(1 + G)\right]^C \sin^2\theta \tag{2-51}$$

where

ρ_p = particle density

ρ_∞ = freestream air density

G = erosion mass loss parameter (described in Section 2.4.2)

θ = local body angle (θ = 90° at the stagnation point)

The constants (C and c) are presumed to be a function of the surface material. Reference 19 indicates that graphite data are best correlated by

$$C = 0.098$$

$$c = 0.317$$

The implementation of the stirring augmentation logic is flagged by the JROUGH flag described in Section 3.1.8. When the stirring augmentation correlation is employed the augmentation factor calculated from Equation (2-51) is compared with the factor calculated from Equation (2-40) and the larger is used.

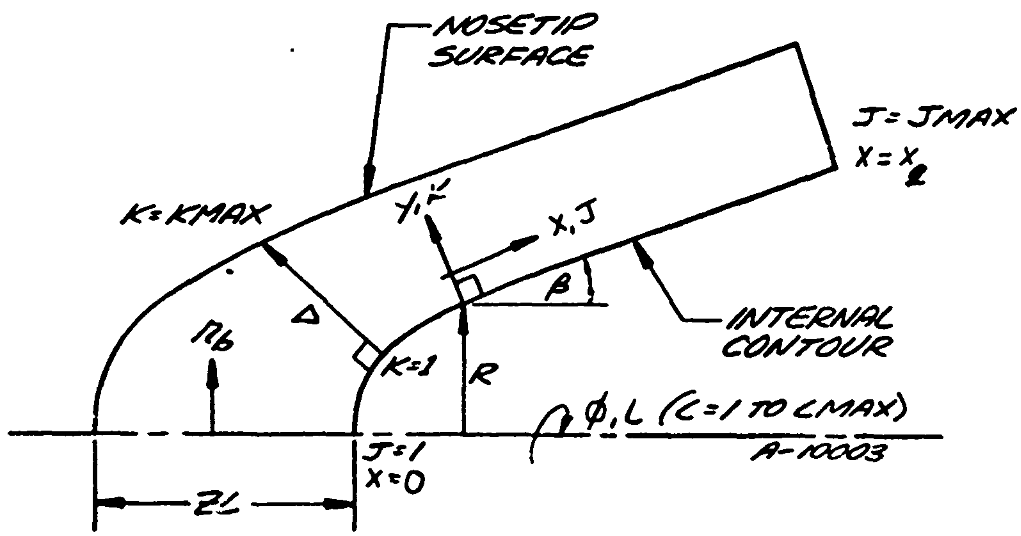
2.3 IN-DEPTH CONDUCTION CALCULATIONS

This section briefly describes the numerical technique used to solve the heat conduction equation inside the nosetip and the coupling between the surface energy balance relations (Section 2.4) and the in-depth conduction solution. The details of the conduction package are described fully by Crowell (Reference 28). In this section only a brief review of the procedure is presented.

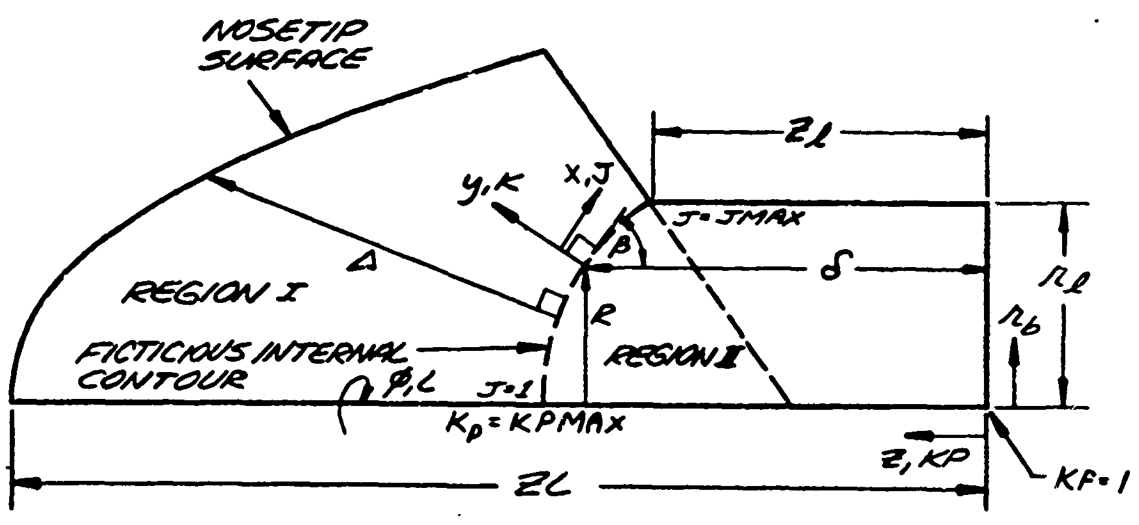
Section 2.3.1 describes the coordinate systems and governing equations. The finite-difference formulations of the differential equations and their solutions are explained in Section 2.3.2. The conduction time step control is discussed in Section 2.3.3.

2.3.1 Coordinate System, Governing Equations

The in-depth coordinate systems for shell and plug geometries are illustrated in Figure 2-6. For the shell geometry a body oriented coordinate system which is located on the internal contour is used (x, y, ϕ). For the plug, the geometry is split into two sections, separated by a fictitious boundary (shown as a dashed line in the figure). The location of the interface between the two sections is chosen such that the geometry of section I is exactly that of the shell configuration. Thus, the coordinate system for region I is also body oriented and located on the fictitious boundary. The shape of the interface



A. SHELL CONFIGURATION



B. PLUG CONFIGURATION

Figure 2-6. Nosetip geometry.

is taken to be spherical for convenience. Cylinderical coordinates are used in region II (the shank portion of the plug).

In the body oriented coordinate system (region I) the heat conduction equation for temperature dependent properties and isotropic conductivities may be written as

$$\rho_m C_p r_b (1+\Lambda Y) \frac{\partial T}{\partial t} = \frac{\partial}{\partial X}\left[\frac{k\, r_b}{1+\Lambda Y}\frac{\partial T}{\partial X}\right] + \frac{\partial}{\partial Y}\left[k\, r_b (1+\Lambda Y)\frac{\partial T}{\partial Y}\right] + \frac{\partial}{\partial \phi}\left[\frac{k(1+\Lambda Y)}{r_b}\frac{\partial T}{\partial \phi}\right] \tag{2-52}$$

where Λ is the curvature of the internal contour or the fictitious interface.

For the cylinderical coordinates (region II) the conduction equation takes the following form

$$\rho_m C_p r_b \frac{\partial T}{\partial t} = \frac{\partial}{\partial r_b}\left(k\, r_b \frac{\partial T}{\partial r_b}\right) + \frac{\partial}{\partial z}\left(k\, r_b \frac{\partial T}{\partial z}\right) + \frac{\partial}{\partial \phi}\left(k \frac{1}{r_b}\frac{\partial T}{\partial \phi}\right) \tag{2-53}$$

It should be noted that due to the axisymmetric assumption, there is no temperature variation in the ϕ-direction, although the conduction package is capable of handling full three-dimensional problems.

The boundary conditions on all surfaces consist of specified heat flux. For most nosetip problems all the boundaries except the receding surface are insulated and these fluxes are zero. In case of the plug geometry the fictitious interface between regions I and II is not a boundary of specified flux or temperature. The temperature distribution along this boundary is computed by requiring that the temperature and heat flux in the regions I and II be identical at the interface. At the receding surface the boundary condition is

$$- k \left.\frac{\partial T}{\partial n}\right|_w = q_{cond}\,(t, T_w, \dot{S}) \tag{2-54}$$

where n denotes the direction normal to the nosetip surface and the functional form of q_{cond} is determined from the surface energy balance formulation (Section 2.4.1).

In order to solve the moving boundary conduction problem over a fixed domain, the surface movement is incorporated into the heat conduction equation through the use of the following transformations

Region I:

$$\eta = \frac{y}{\Delta(t,x,\alpha)} \qquad \tilde{x} = x \qquad \tilde{\phi} = \phi \qquad \tilde{t} = t$$

Region II:

$$S = \frac{z}{\delta} \qquad \tilde{r}_b = r \qquad \tilde{\phi} = \phi \qquad \tilde{t} = t$$

The differential equations (2-52) and (2-53) and the boundary conditions (2-55) are transformed into the new coordinate system and then solved by a finite-difference technique. The description of this finite-difference procedure is given in the following section.

2.3.2 Finite-Difference Formulations

The finite-difference scheme which has been adopted is the Dufort-Frankel method that is an unconditionally stable explicit technique. This method uses a central time difference and therefore, requires storage at two time levels. The Dufort-Frankel method does not require the restrictive time step limitation of standard explicit technique ($\Delta t < \frac{\Delta x^2}{2\alpha}$), but for consistency purposes it requires that Δt goes to zero faster than Δx.

Variable mesh spacing is used throughout. First order derivatives are written in second order central or one sided difference forms and for the second order terms the Dufort-Frankel form is used. For the details of the finite-difference formulation the reader is referred to Reference 28.

When the equations are differenced, the left hand side will contain the temperature of a node (jkl) at the n+1 time level and the right hand side will contain the temperatures of the neighboring nodes at n-1 and n time levels and known geometric parameters. The difference equation is then solved for T^{n+1}_{jkl}. In order to start the calculations both the n-1 and n time levels are set equal to the initial temperature distribution.

In region I, the domain over which the temperatures are obtained from the differential equations runs from J = 2, JMAX-1 in the X-direction, K = 2 to KMAX-1 in the Y-direction and L = 1 to LMAX in the ϕ-direction. In region II, the temperatures are calculated from the differential equations for JP = 2 to JPMAX-1, KP = 2 to KPMAX-1 and L = 1 to LMAX in X, Z and ϕ-directions respectively. In the present axisymmetric code, the computations are only performed in the L = 1 plane. The boundary temperatures are calculated from the finite-difference forms of the boundary conditions.

Following the calculations of the interior point temperatures from the difference equations, the centerline values (X=0, J=1 and JP=1) are obtained by back extrapolation from the known values of J=2 and J=3 nodes. For axisymmetric nosetips the following condition must be satisfied along the centerline:

$$\frac{\partial T}{\partial X} = 0 \tag{2-55}$$

These derivatives are written in one-sided forward difference forms and solved for centerline temperatures including the stagnation point temperature.

The surface temperatures and recession rates are determined from simultaneous solution of the difference form of Equation (2-55) with the surface energy balance relations.

2.3.3 Time Step Control

The computational time steps are controlled by a comprehensive technique to achieve numerical stability, economy and output versatility. The code has, basically, two kinds of time steps: a conduction time step and an environment time step. The print time step is currently set equal to the environment time step.

2.3.3.1 Conduction Time Step

The time step of conduction calculations is the minimum of the following values:

- Explicit finite-difference stability limit: $d^2/4\alpha$ where d is the minimum mesh size and α is the thermal diffusivity of the nosetip material. This is not currently in use because the Dufort-Frankel scheme is unconditionally stable.
- Surface temperature rise control: Δt_{old}(STRD/STRM) where STRD is the input desired surface temperature rise in one time step, and STRM is the maximum surface temperature rise achieved during the previous time step.
- Surface heat flux rise control: $\Delta t_{old}(q_{old}/q_{new})^{CTF}$, where q is the maximum surface heat flux and CTF is the desired growth factor. A recommended expression for CTF in terms of the desired maximum surface temperature rise is the following:

$$CTF = 1.5 + (STRD - 140)/300 \tag{2-56}$$

- Surface recession control: $\delta/\dot{S}_{max}$, where $\dot{S}_{max}$ is the maximum value of surface recession rate and δ is the smallest distance between the first and second nodes in the Y-direction.

At the first conduction step when a majority of the above quantities cannot be calculated, the following time step is also used.

$$\left(\Delta t_c\right)_{first\ step} = \text{STRD}\left(\frac{\rho_m C_P}{\dot{q}}\right)\frac{\delta}{2} \quad (2\text{-}57)$$

2.3.4.2 Environment Time Step

The environment time step determines the frequency with which the inviscid and viscid solutions are to be updated and is equal to the user specified value in the absence of time step stability criteria. In the presence of stability criteria, the environment is redefined whenever either one or both of the following conditions are satisfied.

- If the local surface temperature changes by a factor greater than 1.4.
- If the tangent of the local body angle changes by a factor of two or more.

The reference condition for the above two tests is the last environment definition.

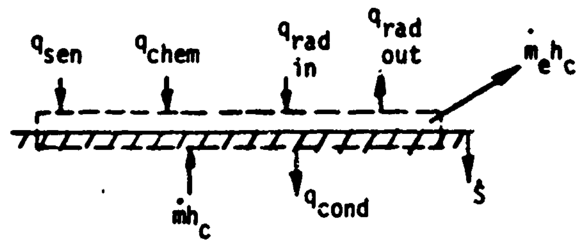
The computation time step, DTH, is the minimum of the conduction and the environment time steps. Furthermore, the computation is automatically terminated if the computed time step is less than the user specified minimum, DLTMIN.

2.4 SURFACE ABLATION RESPONSE CALCULATIONS

The formulation of the surface energy balance technique used to compute the surface ablation response is discussed in Section 2.4.1; modeling of erosion due to hydrometer impacts is described in Section 2.4.2; computer codes to provide the necessary input data are described in Section 2.4.3; and simplified means of the surface energy balance equation are presented in Section 2.4.4.

2.4.1 Surface Energy Balance Formulation

The ablation rate and surface temperature at points on the nosetip are determined by accounting for energy, mass, and species conservation at the ablating surface. The sketch below illustrates the ablating surface control



Sketch of Surface Energy Balance Control Volume
and Energy Flux Terms

volume and the energy fluxes of interest. The surface energy balance equation employed is of the convective transfer coefficient type. In the program, this energy balance equation takes the following form:

$$\underbrace{\rho_e u_e C_H (H_r - h_{ew})}_{q_{sen}} + \underbrace{\rho_e u_e C_M \left[\sum (z^*_{ie} - z^*_{iw}) h_i^{T_w} - B'_{tc} h_w\right]}_{q_{chem}} + \dot{m}_{tc} h_c - q_{cond} + \underbrace{\alpha_w q_{rad}}_{\substack{q_{rad} \\ \text{in}}} - \underbrace{F\sigma\epsilon_w T_w^4}_{\substack{q_{rad} \\ \text{out}}} = 0 \qquad (2\text{-}58)$$

Before commencing a term by term discussion of Equation (2-58), however, it will be useful to describe the general nature of this transfer coefficient expression. Like all such expression, Equation (2-58) is an approximation, the usefulness of which depends mainly on the validity of the transfer coefficient approach. A discussion of this subject is far beyond the scope of the present document. It may be observed here that transfer coefficients have successfully correlated both data and "exact" solutions in simple heat or mass transfer problems, and in combined heat and mass transfer problems for unity (or near unity) Lewis number. Equation (2-58) attempts to extend the transfer coefficient approach to both nonunity Lewis number and unequal mass diffusion coefficient problems, still allowing for chemical reactions and net mass transfer effects. This approach was suggested in Reference 20. Its validity is discussed in References 21 and 22.

In Equation (2-58), the term q_{sen} represents the "sensible convective heat flux." Physically, this is the convective heat flux which would occur for a frozen boundary layer and a noncatalytic wall in the absence of mass

transfer;* it excludes all chemical energy contributions. The term q_{sen} is perhaps more usually written in the form

$$q_{sen} = \rho_e u_e C_H \left(H_{s_r} - h_{s_w}\right) \tag{2-59}$$

but, since generally it is more convenient for the user to input H_r rather than H_s, q_{sen} in Equation (2-58) has been written in a modified form in which H_r appears. This form has the additional advantage that the driving force for energy transfer involves only edge gas states. The derivation of the modified form from Equation (2-58) is given in Reference 20 and Reference 21.

The quantity h_{e_w} in the q_{sen} term is part of the input thermochemical data discussed below. The transfer coefficient $\rho_e u_e C_H$ and the recovery enthalpy H_r are time dependent variables computed in the program for each analysis location. The transfer coefficient is automatically modified from the nonblown value to implicitly account for the effect of the computed ablation rates. The following relation is used:

$$\frac{C_H}{C_{H,O}} = \frac{\ln(1 + 2\lambda B'_{tc})}{2\lambda B'_{tc}} \tag{2-60}$$

where

B'_{tc} = implicitly determined normalized thermochemical ablation rate $(\dot{m}_{tc}/\rho_e u_e C_M)$

λ = an input number discussed below

$\frac{C_H}{C_{H,O}}$ = ratio of blown to nonblown Stanton number

Specified values of λ allow the user to fit blowing correction curves of $C_H/C_{H,O}$ versus B'_{tc} to account for special effects in the few cases where these are known with confidence, such as molecular weight effects or variable property effects. In view of the uncertainties, it is generally recommended that $\lambda = 0.5$ be used for laminar flow. A value $\lambda = 0.4$ appears to correlate constant properties for turbulent data somewhat better. For graphite in air, studies have indicated that a value of 0.7 for both laminar and turbulent flow is most appropriate.

*More generally in the presence of chemical reaction it is the diffusive heat flux from the gas to the wall even in the presence of net mass transfer, provided the boundary layer is frozen and the wall is catalytic.

The term q_{cond} in Equation (2-58) is obtained from the in-depth conduction analysis as a function of T_w and $\dot{S}$ (Equation (2-54)).

The term q_{chem} in Equation (2-58) represents the net amount of chemical energy fluxes at the surface. The z*-difference term represents transport of chemical energy associated with chemical reactions at the wall and in the boundary layer, it is the chemical energy parallel to the sensible convective heat flux term. The z* driving forces for diffusive mass transfer include the effects of unequal diffusion coefficients; for equal diffusion coefficients the z*'s reduce to the familiar mass fractions K_i. The $B'_{tc}h_w$ term represents energy leaving the surface in the gross motion (blowing) of the gas adjacent to the surface. The mass transfer coefficient $(\rho_e u_e C_M)$ is obtained from the blown heat coefficient $(\rho_e u_e C_H)$ using a user specified factor, C_M/C_H. Remaining quantities not yet discussed are B'_{tc}, h_{e_w}, $\sum z^*_{ie}h_i^{T_w}$, $\sum z^*_{iw}h_i^{T_w}$, and h_w. T_w does not appear explicitly but is necessary to evaluate the temperature dependent values of various quantities. The quantities T_w, $\sum z^*_{iw}h_i^{T_w}$, and h_w are input by the user as the dependent variables in a table with three independent variables: p, $\rho_e u_e C_M$, and B'_{tc} (if no chemical kinetic effects are considered only two independent variables p and B'_{tc} are required).

Similarly, the quantities $\sum z^*_{ie}h_i^{T_w}$ and h_{e_w} are input as the dependent variables in a table with p and T as independent variables. These tables are typically generated by the thermochemistry codes described below. Further discussion of these tables is given in Section 3.1.9.

Notice that the erosion mass loss rate $(\dot{m}_e)$ does not appear in Equation (2-58). This is because the eroded material is assumed to leave the surface with the enthalpy of the solid (h_c) and, hence, cancels with the net incoming mass rate $(\dot{m})$ to give

$$\dot{m}h_c - \dot{m}_e h_c = \dot{m}_{tc}h_c \qquad (2\text{-}61)$$

where $\dot{m}_{tc}$ is only the thermochemical portion of the total mass rate $(\dot{m})$. The total mass rate $(\dot{m})$ (and hence $\dot{m}_e$) is required, however, in the conduction equation (Equation (2-56)) to compute the net recession rate $(\dot{S})$. The calculation of the erosion mass loss rate $(\dot{m}_e)$ is described in Section 2.4.2.

The surface energy balance solution procedure may be summarized as follows:

1. Obtain H_r, $\rho_e u_e C_{H,O}$, and p from environment definition routines.
2. Reduce the in-depth conduction matrix to calculate the constants in the equation for q_{cond} (Equation (2-54)).

3. Calculate erosion mass loss rate ($\dot{m}_e$)

4. Correct or adjust $\rho_e u_e C_{H,O}$ for blowing effects

5. Compute $\rho_e u_e C_M = (C_M/C_H)(\rho_e u_e C_H)$

6. Assume B'_{tc}

7. With p, $\rho_e u_e C_M$, and B'_{tc}, look up in input surface thermochemistry tables values of T_w, $\sum z^*_{iw} h_i^{T_w}$, h_w

8. With p and T_w, look up in input edge gas thermochemistry table values of $\sum z^*_{ie} h_i^{T_w}$, h_{e_w}

9. Construct Equation (2-58), noting departure from zero, if any

10. Adjust B'_{tc} quess to reduce departure from zero (Newton-Raphson correction)

11. Go to Step 4 and continue

This procedure converges on a new B'_{tc} value in very few iterations. The same procedure may be used with T_w as the independent variable and B'_{tc} as a dependent variable.

2.4.2 Erosion Modeling

Surface erosion due to hydrometer particle impacts is modeled by two different types of correlations depending on the surface material. For graphite type brittle materials the erosion mass loss correlation is of the form

$$\frac{\dot{m}_e}{\dot{m}_{in}} = G = A_1 u_\infty^b m_p^c \sin \theta^d \qquad (2\text{-}62)$$

where

$\dot{m}_e$ = erosion mass loss flux

$\dot{m}_{in} = \rho_c u_\infty \sin \theta$ = incoming particle mass flux

ρ_c = mass of particles per unit volume of air

u_∞ = vehicle velocity

$m_p = \pi d_p^3 \rho_p / G$ = individual particle mass

d_p = particle diameter

θ = local body angle relative to the axis (θ = 90° at the stagnation point)

The constants (A_1, b, c and d) in Equation (2-62) are determined by correlation of ground test data for each given material. For materials which char (i.e., carbon phenolic) a different set of constants is required for the charred and virgin plastic materials. The two erosion rates predicted for a fully charred and virgin surface are "bridged" together based on the relative rates of surface erosion and in-depth char generation. Additionally the body angle (θ) dependence in Equation (2-62) does not fully collapse all carbon phenolic data and, hence, low and high angle erosion correlation constants are required as well as a "bridging" function. Currently specific erosion correlation constants and bridging functions are built into the code for carbon phenolic. Reference 19 discusses the details of this modeling and Reference 23 covers the graphite erosion models. The input section (Section 3.1) describes how these specific correlations may be evoked.

For malleable type metal materials the erosion mass loss correlation is of the form

$$\frac{\dot{m}_e}{\dot{m}_{in}} = G = \frac{u_\infty^2}{C_N} \qquad (2\text{-}63)$$

where

C_N = damage coefficient

The damage coefficient (C_N) is determined from experiment and is primarily a function of surface temperature (T_w). Typically the damage coefficient decreases as the surface temperature approaches the melt temperature. Built-in values of C_N versus T_w are available for tungsten. Reference 19 gives the details of the tungsten correlation and the input section tells how it may be evoked.

The input required for erosion calculations is the cloud profile, which is a table of:

- Mass concentration (ρ_c)
- Particle diameter (d_p)
- Particle specific gravity (γ_s)

versus altitude.

2.4.3 Use of Thermochemistry Codes to Generate Input Data

Section 2.4.1 above makes it clear that some complex tabular thermochemical input is required if the surface energy balance boundary condition is to be used. These tables are generated by any one of a number of separate computer codes. The most recent such code is designated General Nonequilibrium

Ablation Thermochemistry Code (GNAT). It is a general open and closed system thermochemical nonequilibrium code specifically constructed for this purpose (Reference 24). Other Aerotherm thermochemistry codes which treat only equilibrium thermochemistry are in existence. The most recent of these is the Equilibrium Surface Thermochemistry Code, Version 3 (EST3), which is described in Reference 25. A generally similar code which differs from EST3 only in added detail is designated ACE and is described in Reference 26. An older version of EST3 was designated EST2 and is described in Reference 27. To obtain the necessary data tables for input, the user selects sets of values for the pressure (p), transfer coefficient ($\rho_e u_e C_M$), and nondimensional thermochemical ablation rate (B'_{tc}). (Note, if chemical kinetics are not considered the only parameters required are pressure (p) and ablation rate (B'_{tc}).)

The user specifies the elemental composition of the environment gas and the ablating material, and supplies some general species thermochemical data for all molecules to be considered in the system. Finally, the user specifies the unequal diffusion coefficients if they are important. The thermochemistry code then computes all the dependent quantities of interest at each table point in the $p \times B'_{tc}$ matrix of independent variable values, namely, T_w, $\sum z^*_{iw} h_i^{T_w}$, and h_w, and punches this information on cards. Similarly, the tables of $\sum z^*_{ie} h_i^{T_w}$ and h_{e_w} values are prepared as functions of p and T, and punched out on cards. All these cards form part of the Table 09 card input deck (see Section 3.1.9).

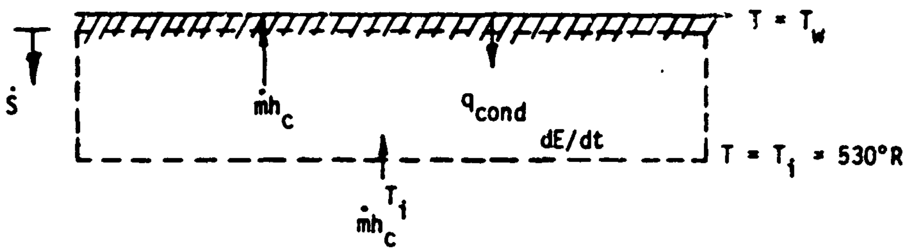
2.4.4 Simpler Forms of the Surface Energy Balance Equation

As noted in Section 2.5.2 above, for equal diffusion coefficients the z_i^* driving forces reduce to the simple mass fractions K_i. If in addition to equal diffusion the user specifies that $\rho_e u_e C_M = \rho_e u_e C_H$, then since $\sum K_{ie} h_i^{T_w} = h_{e_w}$ and $\sum K_{iw} h_i^{T_s} = h_w$ by definition, Equation (2-58) simplifies to the more familiar form

$$\rho_e u_e C_H \left(H_r - (1 + B'_{tc}) h_w \right) + \dot{m}_{tc} h_c - q_{cond} + \alpha_w q_{rad} - F\sigma\epsilon T_w^4 = 0 \qquad (2\text{-}64)$$

In this expression h_{e_w} and $\sum z^*_{ie} h_i^{T_w}$ do not appear, hence the corresponding table is not necessary and need not be included in the input (see Section 3.1.9 below).

A steady state ablation option is also available. If this option is specified the q_{cond} term in Equation (2-58) is calculated by taking an energy balance on a control volume extending from below the ablating surface down to the thermally unaffected material (see the following sketch).



Sketch of Control Volume Around Thermally Effected Material

Energy conservation on the above control volume gives

$$\dot{m}h_c - q_{cond} = \dot{m}h_c^{T_i} - \frac{dE}{dt} \qquad (2\text{-}65)$$

where

$h_c^{T_i}$ = the enthalpy of the thermally uneffected material before exposure (T_i is assumed to be 530°R)

$\frac{dE}{dt}$ = rate of energy storage in control volume

The steady state assumption implies that dE/dt is zero and corresponds to the physical situation when the temperature profile relative to the moving surface is invariant with time. The assumption is accurate for low conductivity ablators and for high ablation rate situations. By considering dE/dt = 0, q_{cond} may be calculated from Equation (2-65) as

$$q_{cond} = \dot{m}\left(h_c - h_c^{T_i}\right) \qquad (2\text{-}66)$$

Notice that for the steady state assumption, q_{cond} is independent of material thermal properties and response history.

2.5 SURFACE POINT MOVEMENT AND SURFACE SMOOTHING

The surface energy balance determines the recession rate normal to the surface at each body calculation point. Based on the time step size (Δt) these points are then moved the corresponding distance to define new body points at the end of the time step. The new body points are then used to define new surface inclination angles at the body points. In a typical nosetip shape change problem the size of important geometric features in the stagnation region decreases in turbulent flow, and eventually becomes smaller than can be efficiently modeled with typical body point spacing. When a numerically limited nose radius is reached logic is applied to define an apparent nose radius.

The numerics of shape change are described in the following sections. The shape change geometry for body point movement is described in Section 2.5.1; surface angle definition techniques are presented in Section 2.5.2; and the apparent nose logic is discussed in Section 2.5.3.

2.5.1 Shape Change Geometry

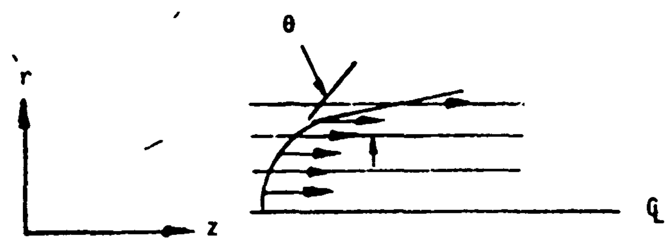
With reference to Figure 2-6, the location and shape of the surface is completely defined by $\Delta(X,\phi,t)$. The rate of change of Δ with time can be related to the surface normal recession rate, $\dot{S}$ by the following equation:

$$\frac{\partial\Delta}{\partial t} = -\dot{S}\left[1 + \left(\frac{\partial\Delta/\partial X}{1+\Lambda\Delta}\right)^2 + \left(\frac{\partial\Delta/\partial\phi}{R+\Delta\cos\beta}\right)^2\right]^{1/2} \tag{2-67}$$

where Λ, R and β are the geometric parameters of the internal contour defined, respectively, as: curvature, radial distance from the nosetip axis and angle of inclination with respect to the nosetip axis.

The Equation (2-67) is written in an explicit finite-difference form and solved for the values of Δ at the n+1 time step. Along the centerline where R = 0, Equation (2-67) is not applied and the condition $\partial\Delta/\partial X = 0$ is used to determine the new position of the stagnation point.

In the steady state conduction option the body points are moved along lines of constant radius as indicated by the sketch below.



The relation for the amount of axial movement is

$$\Delta z = \frac{\dot{S}_{normal}\,\Delta t}{\sin\theta} \tag{2-68}$$

When using the steady state energy balance, conduction considerations do not limit time step size; hence, the only consideration limiting time step size is shape change. In other words, the calculated recession rate distribution cannot be applied over such a time span that the body shape (and, hence, recession rate distribution) changes in a drastic manner. The criteria applied is that the tangent of the local body angle may not change by more than a factor of two.

2.5.2 Surface Angle Definition

Numerical shape change calculation techniques are strongly sensitive to the method used to define the local surface angle since this angle strongly influences the surface pressure, heat transfer, ablation, and erosion calculations. Circular curve fits and straight line interpolation techniques are available.

The circular curve-fit method involves basically fitting a circular arc through the point of interest and the points on either side (i.e., three points define a circle). The body angle is then defined as the tangent to the circle at that point. Exceptions are taken to this definition if the radius of curvature is negative in order to avoid unrealistic concave shapes.

2.5.3 Apparent Nose Model

As shape change proceeds on nosetips for which transition is near the nose, the stagnation point radius of curvature becomes too small to model with the typical body point spacing. The code has internal logic to determine when this numerically limited nose radius is reached, and at that time an effective spherical nose radius is computed. This specification controls only the detail at the stagnation point and does not limit or redefine the overall shape of the nosetip.

The apparent nose radius logic used with the circular curve fits involves basically fitting a tangent sphere into the "cone" formed by the second and third body points, and is primarily based on geometrical considerations.

Neither of the apparent nose radius or body angle definition techniques described above is completely successful in predicting all observed nosetip shape change regimes. Hence, both must still be considered to be in the developmental stage.

SECTION 3

DESCRIPTIONS OF INPUT AND OUTPUT

This section provides detailed user oriented instructions for code input and a description of the output. The input instructions are described in Section 3.1 and output features are covered in Section 3.2.

3.1 INPUT INSTRUCTIONS

The input to the code can be read either from data cards for an initial run or from magnetic tape or disk for a restart run. The details of the input for each of these types of runs are described below. The basic input for an initial run consists of:

- One restart information card.
- Three title cards.
- Nine input tables.

Not all nine of the input tables are required for every run. Each table is preceded by a single card containing the identifying table number.

For a restart run only the single restart information card is required, the rest of the information is read from magnetic tape or disk.

The following sections describe the restart information, title cards, and nine input tables, respectively.

3.1.1 Restart Information

The "restart" card is the first card in the data deck. If the run is a restart it is the only card required, and tells the code the iteration from which to begin restart. For an initial run the restart card tells the code how often to write restart files. All restart reading and/or writing is done on Logical Unit 11 and it should be assigned accordingly. The restart card format is as follows:

Card No.	Columns	Format	Data	Units
1	1-3	I3	ISKIP - number of environmental calls between restart file writes.	--
	4-6	I3	IRESRT - restart flag 0 - first run no restart >0 - transient restart - read the $IRESRT^{th}$ set of data on Unit 11 to start the run. No other input is required <0 - steady state restart	--

Note that if both ISKIP and IRESRT are equal to zero no data will be read or written on Unit 11 and it need not be assigned.

3.1.2 Title and Heading Information

The second set of input data are three title cards. They are used to transmit title and heading information to the output. The first 72 columns of each of these cards may be used for the title, the alphameric information in columns 61 through 72 of the third card being used as a page heading on all pages after the first.

3.1.3 Table 01 - General Program Constants

These cards supply the code with computation time information and program flags which indicate options to be subsequently read.

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No.	--
2	1-12	E12.5	Initial value of problem time	sec
	13-24	E12.5	Final value of problem time	sec
	25-36	E12.5	First output time increment. This interval represents the time increment for output. Provision for changing this time increment within a run is provided by the NTIC flag described below.	
	37-48	E12.5	DLTMIN - time step stability flag <0 - no stability =0 - set to 10^{-5} sec >0 - stability criteria used	sec

Table 01 (continued)

Card No.	Columns	Format	Data	Units
	49-60	E12.5	CTF - defined by Equation (2-56). If CTF is less than 1.2 or greater than 1.7 it is set to 1.3.	
	61-72	E12.5	STRD - maximum desired surface temperature rise in one conduction time step. If STRD is less than 49 or greater than 201 it is set to 75°R. STRD is not required for the steady state option.	°R
3	1-3	I3	TC - Flag denoting type of transition criterion to be subsequently input in Table 04. TC < 0 denotes transitional heating is used in the surface energy balance and TC > 0 denotes abrupt transition is used. ABS (TC) 0 - all laminar flow (Table 04 is not needed) 1 - momentum thickness Reynolds No. vs. edge Mach No. 2 - run length Reynolds No. vs. edge Mach No. 3 - axial distance vs. altitude 4 - rough wall transition based on $Re_k \left(\frac{s}{\delta^*}\right)^{1/3} = \begin{cases} 2300, & \text{onset} \\ 2000, & \text{location} \end{cases}$ (Table 04 is not needed) 5 - rough wall transition based on $Re_\theta \left[\frac{1}{\left(\frac{B'}{10} + 1 + \frac{B'}{4}\,\frac{\rho_e}{\rho_w}\right)}\,\frac{k}{\theta}\right]^{0.7} = \begin{cases} 255, & \text{onset} \\ 215, & \text{location} \end{cases}$ (Table 04 is not needed) 6 - fully turbulent flow (Table 04 is not needed	--
	4-6	I3	ENV - flag denoting environment option to be subsequently read in Table 02 1 - flight option 2 - wind tunnel	--

Table 01 (continued)

Card No.	Columns	Format	Data	Units
			3 - ballistic range 4 - general 5 - arc heater	
	7-9	I3	CF - flag controlling curve fit and apparent nose option 0 - circular curve fits and no apparent nose logic 2 - circular curve fits and apparent nose	--
	10-12	I3	SO - special output flag 0 - boundary layer solution only (no ablation or shape change). 1 - general problem with ablation and shape change. Shape profiles written on file 15	--
	13-15	I3	NTIC - number of time interval changes (not number of time intervals) $NTIC_{max}$ = 10. A non-zero entry in this column causes sets of time interval changes to be read from the next card.	--
	16-18	I3	ISS - conduction option flag 0 - transient conduction option. Sphere-cone initial geometry with geometric progression distributions of surface and in-depth grids. 1 - steady state conduction option. Initial geometry and surface point distributions same as above. 2 - steady state conduction option. General initial geometry and surface points distribution. The details of this input are described in Section 3.1.5.	--
	19-21	I3	IPRNT - flag which determines the amount of environmental output at print times. Six output tables are available and the contents of each is described in Section 3.2.2.1. IPRNT < 0 denotes output for each integration point and IPRNT > 0 denotes output for body points only.	--

Table 01 (concluded)

Card No.	Columns	Format	Data	Units
			ABS (IPRNT) 0 or 1 - print Table 1 2 - print Tables 1 and 2 3 - print Tables 1, 3, 4 and 5 4 - print Tables 1, 3, 4, 5 and 6.	
	22-24	I3	LPRNT - flag similar to IPRNT which determines the amount of output at intermediate computation times (i.e., when computation time not equal to print time). LPRNT < 0 denotes output for each integration point and LPRNT > 0 denotes output for body points only.	--
			ABS (LPRNT) 0 - no output 1 - abbreviated output of environment and recession only 2 - print Tables 1 and 2 3 - print Tables 1, 3, 4 and 5 4 - print Tables 1, 3, 4, 5 and 6.	
4	This card supplies information for changes in the output time interval and is read only if NTIC > 0.			
	1-12	E12.8	Second output time interval	sec
	13-24	E12.8	Time for change to second output time interval	sec
	25-36	E12.8	Third output time interval	sec
	37-48	E12.8	Time for change to third output time interval	sec
	49-60	E12.8	Fourth output time interval	sec
	61-72	E12.8	Time for change to fourth output time interval	sec
5 (etc)	Same for NTIC output time interval changes. Three sets per card, to a maximum of ten sets.			

3.1.4 Table 02 - Environment Table

The basic environment information required by the code is the freestream state (pressure and density) and vehicle/gas relative velocity. Given this

Table 02 (continued)

information the code performs real gas calculations for air to find the stagnation conditions. To aid the user in performing calculations for various common flight and ground test facility environments, five environment input options are provided. They are:

1. Flight environment - input altitude and velocity as a function of time; free stream conditions are found from a built-in ARDC standard atmosphere table.
2. Wind tunnel environment - input supply pressure and temperature as a function of time as well as free stream Mach No. and ratio of specific heats (γ); free stream conditions are found based on assumed air isentropic expansion at constant γ.
3. Ballistic range environment - input projectile velocity and range pressure as a function of time; air assumed to be at 75°F to obtain free stream density.
4. General environment - input free stream pressure, density, and velocity as a function of time.
5. Arc heater environment - input consists of a quantitative description of the arc heater flow field and of the start-up transient which the model experiences when injected into this flow field.

For the flight, wind tunnel, ballistic range, and general environment options, Table 02 is basically a time table of environment conditions. For the arc heater option the environment is more complex and in this case Table 02 provides input of both the spacial and temporal variation of environment.

There are a maximum of 50 entries in this table; at least two entries are required.

3.1.4.1 Input for Flight Option, ENV = 1

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No. 02	--
2	1-2	I2	Must be blank	--
	3-14	E12.8	Time	sec
	15-26	E12.8	Altitude	ft
	27-38	E12.8	Velocity	ft/sec
3 (etc)	Same as Card No. 2 for increasing time.			--

Table 02 (continued)

3.1.4.2 Input for Wind Tunnel Option, ENV = 2

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No. 02	--
2	1-2	I2	Must be blank	--
	3-14	E12.8	Time	sec
	15-26	E12.8	Supply pressure	psia
	27-38	E12.8	Supply temperature	°F
	39-50	E12.8	Free stream ratio of specific heats (Card No. 2 only)	--
	51-62	E12.8	Free stream Mach No. (Card No. 2 only)	--
3	1-2	I2	Must be blank	--
	3-14	E12.8	Time	sec
	15-26	E12.8	Supply pressure	psia
	27-38	E12.8	Supply temperature	°F
4 (etc)	Same as Card No. 3 for increasing time.			

3.1.4.3 Input for Ballistic Range Option, ENV = 3

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No. 02	--
2	1-2	I2	Must be blank	--
	3-14	E12.8	Time	sec
	15-26	E12.8	Range static pressure	atm
	27-38	E12.8	Projectile velocity	ft/sec
3 (etc)	Same as Card No. 2 for increasing time.			

3.1.4.4 Input for General Environment Option, ENV = 4

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No. 02	--
	1-2	I2	Must be blank	--

Table 02 (continued)

Card No.	Columns	Format	Data	Units
	3-14	E12.8	Time	sec
	15 26	E12.8	Free stream static pressure	atm
	27-38	E12.8	Free stream static density	lb/ft^3
	39-50	E12.8	Free stream velocity	ft/sec
	51-62	E12.8	Ratio of specific heats (Card No. 2 only)	--
3	1-2	I2	Must be blank	--
	3-14	E12.8	Time	sec
	15-26	E12.8	Free stream static pressure	atm
	27-38	E12.8	Free stream static density	lb/ft^3
	39-50	E12.8	Free stream velocity	ft/sec
4 (etc)	Same as Card No. 3 for increasing time, maximum of 50 entries.			

3.1.4.5 Input for Arc Heater Environment

The free stream environment produced by an arc plasma generator, such as the AFFDL 50 MW RENT facility, has characteristics distinctly different from the environment options described above (ENV = 1-4). In general, the pressure level is constant with time but varies with distance from the nozzle exit because of nonparallel flow streamlines. Input consists of one card containing the steady operating conditions (including model location) and a table of normal shock total pressure ratio as a function of distance from the nozzle exit.

An option also exists for specifying a free stream pressure variation during a start-up transient. The ratio of instantaneous total free stream pressure to the steady value for two or more times are input. The option is flagged by reading in a nonzero entry for the length of the start-up transient (DTIME) which is read from the second card. The values of total pressure ratio versus time are input using the same read statement which specifies the spacial variation of pressure ratio, by adding 100 to each of the times. Again a maximum of 50 entries is allowed.

Table 02 (concluded)

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No. 02	--
2	1-2	I2	Must be blank	--
	3-14	E12.8	$P_{t_{\infty steady}}$, total free stream pressure	atm
	15-26	E12.8	H_o, total enthalpy	Btu/lb
	27-38	E12.8	X_o, axial distance from nozzle exit plane to stagnation point (assumes model advance with recession)	in.
	39-50	E12.8	K_1, multiplying constant in the Fay & Riddell stagnation point heating relation (if $K_1 = 0$, it is set to 1.0)	--
	51-62	E12.8	DTIME - Duration of start-up transient	sec
	63-74	E12.8	γ, specific heat ratio (if $\gamma = 0$, it is set to 1.2)	--
3	1-2	I2	Must be blank	--
	3-14	E12.8	X, distance from nozzle exit plane	in.
	15-26	E12.8	$P_{t_2}/P_{t_{\infty steady}}$, pressure ratio	--
4 (etc)	Same as Card No. 3 for increasing X values.			
n	1-2	I2	Must be blank	--
	3-14	E12.8	Time + 100	sec
	15-26	E12.8	$P_{t_\infty}/P_{t_{\infty steady}}$, pressure ratio	--
n+1	Same as Card No. n for increasing time, maximum of 50 entries including Card No. 3. There must be at least two x-values and two time values when this option is used. Time variant environment logic is not debugged.			

3.1.5 Table 03 - Geometry

In the first part of this section initial geometry and in-depth grid are described and in the second part the input format of Table 03 is explained.

3.1.5.1 Initial Geometry

The initial body geometry is input as a table of coordinates for several points on the body. This input is different for steady state and transient conduction options. The differences are described below.

Table 03 (continued)

1. Transient conduction option - a sphere cone initial geometry and geometric progression distribution of body points are assumed. Input sphere radius, cone half angle, number of body points and the common ratio of the geometric progression. The initial geometry may be of a shell or plug category. For a shell, the internal contour is assumed to be a sphere cone whose sphere radius and cone half angle are input. For a plug, the shank geometry is input. The conduction option flag in this case is ISS = 0. The details of these inputs are described in Section 3.1.5.4.

2. Steady state option - under this option, three types of input are possible for initial geometry and surface point distributions:

   - Sphere cone geometry and geometric progression distribution of surface points. This input is the same as the transient option input. The conduction option flag in this case is ISS = 1.
   - Sphere cone geometry with uniform surface point distribution. Input sphere radius, cone half angle, axial length and number of body points desired on sphere and cone.
   - General body - input a table of up to 30 body coordinates (r,z). The conduction option flag in the above two cases is ISS = 2.

3.1.5.2 In-Depth Grid

The input of the in-depth grid applies only to the transient conduction option of the code. The in-depth grid system is shown on Figure 2-6. Since the code is presently limited to axisymmetric geometries, we will only consider the grid distributions in the X- and η-directions.* Geometric progression distributions of grids in both X- and η-directions are assumed. Therefore it is only required to input the number of the grid points and the common ratios in X- and η-directions.

3.1.5.3 Surface Temperature

The code assigns one input value of surface temperature to all body points for all input options except the general body. If no surface temperature is specified, a default of 530°R is utilized. For the general shape option a surface temperature distribution can be input.

---

*η defined on Page 2-28.

Table 03 (continued)

3.1.5.4 Table 03 Input Format

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No. 03	--

Read The Following Cards Only if ISS = 0 or 1. If ISS = 2 go to page 3-14.

Card No.	Columns	Format	Data	Units
2	1-4	4A	PS - = "PLUG" or "SHEL", specifying the nosetip geometry	--
	9-13	4A	SB - ignored if PS = "PLUG", must be "SOLI" if a solid body is desired. The solid body is a shell with no internal contour.	--
3	1-5	I5	ABLATE - integer variable defining surface movement. = 0 surface movement is specified in subroutine TRANS = 1 surface movement is calculated in subroutine ABL8	--
	6-10	I5	MOVE - integer variable defining surface movement = 0 no surface movement = 1 allow surface movement If ABLATE = 1, MOVE must = 1	--
	11-15	I5	KAPFLG - has meaning for shell geometry only = 1 zero curvature of the internal contour and BETA = $\pi/2$, ZJ = XJ, ZB = 0 and KAPPA = 0 = 0 finite curvature of the internal contour	--
	16-20	I5	IPHI - flag for extrapolation in ϕ-planes. Applies only to three-dimensional in-depth computations. = 0 all back extrapolations to be done for half the ϕ-planes; the other half are defined symmetrically = 1 the back extrapolation to be done for L=1 only; the other planes are set to the L=1 values	--

Table 03 (continued)

Card No.	Columns	Format	Data	Units
	21-25	I5	NOSYM - flag for symmetry in ϕ-direction Applies only to three-dimensional shape change calculations. = 0 assumes a symmetry plane = 1 implies no symmetry	--
	26-30	I5	IZERO - flag for angle of attack = 1 zero angle of attack; T7FLG and T22FLG will be turned on, NOSYM set to zero and LMAX=3. In the present axisymmetric calculations, a value of 1 should be entered for IZERO.	--
4	1-5	I5	JMAX - number of X steps +1 (maximum of 23)	--
	6-10	I5	KMAX - number of η steps +1 (maximum of 36)	--
	11-15	I5	LMAX - number of ϕ steps +1 (maximum of 3)	--
5	1-10	F10.0	AE - controls the mesh spacing in the η-direction	--
	11-20	F10.0	AX - controls the mesh spacing in the X-direction AE and AX are the common ratios of the geometric progressions for grid distributions in η- and X-directions. For uniform mesh, set AE=AX=1. For a fine body point distribution near the stagnation point enter AX>1, and for a fine in-depth grid near the nosetip surface enter AE<1.	--

Geometric Parameters Relative To The Internal Contour
(For a plug these variables are calculated internahly and the input values ignored.)

Card No.	Columns	Format	Data	Units
6	1-10	F10.0	RN - nose radius	ft
	11-20	F10.0	THC - cone half angle	deg
	21-30	F10.0	XLEN - maximum X-distance. In the SOLID case, XLEN must be an angle in radians.	ft, rad

Table 03 (continued)

Card No.	Columns	Format	Data	Units
	31-40	F10.0	BSUBB - square of the ratio of the major to minor axis of an ellipse. Enter a value of 1 for spherical contour.	--
7	1-10	F10.0	T2FLG - flag for X-variation = 1 no X-variation, TERM2 and T2 are internally set to 0 = 0 allow X-variation	--
	11-20	F10.0	T7FLG - flag for ϕ-variation = 1 no ϕ-variation, TERM7 and T2 are internally set to 0 = 0 allow ϕ-variation In the present code enter a value of 1 for this flag.	--

Cards 8, 9 and 10 Are To Be Input For The Plug Geometry Only

Card No.	Columns	Format	Data	Units
8	1-10	F10.0	GAMMA - angle from the horizontal that defines the inclination of the plug shank	deg
	11-20	F10.0	RLEN - radius of the plug shank (r_1)	ft
	21-30	F10.0	ZLEN - length of the plug shank (Z_1)	ft
9	1-5	I5	KPMAX - number of Z steps +1	--
10	1-10	F10.0	T22FLG - flag for ϕ-variation in the shank = 1 no ϕ-variation; T22 is set equal to zero = 0 allow ϕ-variation	--
11	1-10	F10.0	TINITL - initial temperature of the body	°R

Geometric Parameters Relative To The External Contour

Card No.	Columns	Format	Data	Units
12	1-10	F10.0	RN2 - nose radius	ft
	11-20	F10.0	THETA2 - cone half angle	deg
	21-30	F10.0	ZL - nosetip overhang for SHEL; total axial length for PLUG or SOLID (see Figure 2-6)	ft
13	1-5	I5	NNMAT - material index assigned to all surface and in-depth grid points	--

Table 03 (concluded)

Card No.	Columns	Format	Data	Units
Read The Following Cards Only if ISS = 2				
2	1-5	I5	NS - number of points on the body surface (maximum 30 points) >0 sphere-cone geometry ≤0 general shape	--
	6-10	I5	NPN - number of points on the nose; applicable only to sphere-cone option (NS>0)	--
	11-20	F10.5	RSTAGI - initial nose radius	ft
	21-30	F10.5	ZMAX - maximum axial length (sphere-cone option only)	ft
	31-40	F10.5	ANGLI - initial cone half angle (sphere-cone option only)	deg
	41-50	F10.5	TS - initial body temperatures If entered zero, it is set to 530°R	°R
General Shape Option Only - (read only if NS≤0)				
3	1-2	I2	NC - flag to read the coordinates of the body points = 0 keep reading ≠ 0 stop reading. This indicates that the card is the last of its kind.	--
	3-14	E12.8	ZSP - body point axial length measured from the stagnation point	ft
	15-26	E12.8	RSP - body point radial length	ft
	27-38	E12.8	ATS - body point temperature. If entered zero, it will be set to TS	°R
	39-40	I2	IMAT - body point material index	--
4 (etc)	Same as Card No. 3 for the rest of the body points.			

3.1.6 Table 04 - Transition Criteria

This table communicates criterion for specifying when boundary layer transition occurs. Of the six transition criteria available three require tabular information which is transmitted through this table; they are momentum thickness Reynolds No. (Re_θ) vs local Mach No. (M_e), run length Reynolds No. (Re_s) vs local Mach No. (M_e) and axial transition location vs altitude. The TC flag read with the general constants denotes which criterion applies. This table must contain at least two, but no more than 30 entries.

3.1.6.1 Input for Re_θ versus M_e (ABS(TC) = 1)

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No. 04	--
2	1-2	I2	Must be blank	--
	3-14	E12.8	Local edge Mach No. (M_e)	--
	15-26	E12.8	Transitional momentum thickness Reynolds No. (Re_θ)	--
3 (etc)	Same as Card No. 2 for increasing M_e.			

3.1.6.2 Input for Re_s versus M_e (ABS(TC) = 2)

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No. 04	--
2	1-2	I2	Must be blank	--
	3-14	E12.8	Local edge Mach No. (M_e)	--
	15-16	E12.8	Transitional run-length Reynolds No. (Re_s)	--
3 (etc)	Same as Card No. 2 for increasing M_e.			

3.1.6.3 Input for Axial Transition Location vs Altitude (ABS(TC) = 3)

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No. 04	--
2	1-2	I2	Must be blank	--

Table 04 (concluded)

Card No.	Columns	Format	Data	Units
	3-14	E12.8	Altitude	ft
	15-26	E12.8	Axial transition location	in.
3 (etc)	Same as Card No. 2 for increasing altitude.			

3.1.7 Table 05 - Weather Conditions

This table inputs the hydrometer environmental conditions for use in performing erosion calculations. The input consists of certain erosion calculation flags and a cloud altitude profile. This table is not required for clear air calculations.

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No. 05	--
2	1-5	I5	NCL - number of cloud entries. If NCL < 0, altitudes are in meters	
	6-15	E10.2	Maximum altitude of cloud	ft or m
	16-25	E10.2	Minimum alaitude of cloud	ft or m
	38-39	I2	NOSLO - particle shock layer slow-down flag 0 - no slowdown 1 - particles are slowed down as they impinge on the shock wave 2 - particle mechanical breakup model employed	--
	40-41	I2	NOHEAL - crater roughness healing flag 0 - no healing of craters 1 - crater healing by ablation is modeled	--
3	1-10	F10.5	Altitude (independent variable). The units are dictated by the meter flag.	ft or m
	(2-62))	(2-62)	(2-58)	

Table 05 (concluded)

Card No.	Columns	Format	Data	Units
	11-20	F10.5	Particle mass concentration	gm/m^3
	21-30	F10.5	Particle diameter	$m\times10^{-6}$ (micron)
	31-40	F10.5	Particle specific gravity. If entered as zero it is set to 1.0.	--

This table must contain at least two but no more than 20 entries and the altitudes must be entered in an increasing order.

3.1.8 Table 06 - Material Properties

Table 06 is used to input material surface roughness and thermal properties. The material index number (MAT) assigned to a given material need (in general) only be consistent with the material indices used in the nosetip configuration input (Table 03). If, however, hydrometer erosion effects are to be included the following assignments must be followed due to built-in values for certain of the erosion correlations.

- Carbon phenolic MAT = 2
- Tungsten MAT = 3

Two types of surface roughness are input:

- Laminar or intrinsic roughness (k_i) which is used for rough wall transition criteria and in calculating roughness augmentation to laminar heating.
- Scallop or turbulent roughness (k_t) which is used in calculating the roughness augmentation to turbulent heating.

Turbulent surface roughness may be input either as a constant or calculated according to $k_t = K_1 p_e^{-0.77}$ where K_1 and a maximum roughness height are input.

Three roughness heating augmentation options are allowed for; they are

- No roughness heating augmentation.
- Laminar and turbulent heating augmentation according to the models described in Section 2.2.4 - but no hydrometer stirring effects.
- Same as above - but including hydrometer stirring effects.

Table 06 (continued)

The material thermal properties required include certain constants (i.e., density, heat of formation, etc.) plus tabular values of quantities which are a function of temperature (i.e., specific heat, conductivity, and emissivity). Notice that for the steady state conduction option the specific heat and conductivity are not required and may be entered as dummy values (e.g., 1.0).

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No. 06	--
2	1-2	I2	MAT - material index. If erosion effects are included use the following assignments. 1 - graphite 2 - carbon phenolic 3 - tungsten	--
	3-10	E8	RHO - material density	lbm/ft^3
	11-20	E10.5	TFO - datum temperature for heat of formation. For JANNAF data, TFO = 536°R	°R
	21-30	E10.5	HFO - heat of formation	Btu/lbm
	31-40	E10.5	TBRPL - laminar blowing rate reduction parameter. λ in Equation (2-60).	--
	41-50	E10.5	TBRPT - turbulent blowing rate reduction parameter. λ in Equation (2-60).	--
3	1-2	I2	NERODE - erosion law number =1 generalized input (read the next card) =2 carbon phenolic erosion model =3 tungsten erosion model	--

-----Next card input the constants of erosion law (Equation (2-62))-----
(for NERODE = 1 only)

Card No.	Columns	Format	Data		Units
4	1-10	F10.4	A_1	Constants in Equation (2-62)	--
	11-20	F10.4	b		--
	21-30	F10.4	c		--
	31-40	F10.4	d		--

Table 06 (concluded)

Card No.	Columns	Format	Data	Units
5	1-2	I2	JROUGH - roughness heating augmentation flag. 0 - no augmentation 1 - roughness augmentation, but no stirring augmentation 2 - roughness and stirring augmentation	--
	3-14	E12.8	RUFL - intrinsic roughness height, k_i	in.
	15-26	E12.8	RUFMAX - turbulent roughness height flag >0 - constant turbulent roughness equal to RUFMAX <0 - calculate turbulent roughness according to $k_t = K_1 p_e^{-0.77}$ with $k_{t_{max}}$ = ABS (RUFMAX)	in.
	27-38	E12.8	K1 - turbulent roughness height at p_e = 1 psia. Read only if RUFMAX < 0.	in.
6	1-2	I2	NC - flag, nominally zero, +1 marks terminal card of last material property table, -1 marks terminal card of other intermediate material property tables.	--
	3-10	F10.5	Temperature (independent variable)	°R
	11-20	F10.5	Specific Heat	Btu/lb-°R
	21-30	F10.5	Thermal conductivity	Btu/ft-sec-°R
	31-40	F10.5	Emissivity	--

This table must contain at least two but no more than 30 entries.

Currently Tables 07 and 08 are reserved for future use.

3.1.9 Table 09 - Surface Thermochemistry

Table 09 consists of the parameters necessary to utilize the surface energy balance formulation described in Section 2.4. The following paragraphs describe the input for a given material.

Table 09 (continued)

A single lead card specifying the material index is read first, followed by a card containing control integers, followed by a set of tabular thermochemistry data cards.

3.1.9.1 Table No. and Constants

Card No.	Columns	Format	Data	Units
1	1-2	I2	Table No. 09	--
2	1-5	I5	MAT - material index no.	--
3	1-5	I5	NBPF - flag controlling reading of mechanical fail quantity (for use with blowing correction) NBPF 0 - no mechanical removal 1 - mechanical removal term read and used to reduce blowing rate	--
	6-15	F10.5	CMH - ratio of mass to heat transfer coefficients (typically 1.0).	--

3.1.9.2 Edge Enthalpy Data

Equation (2-58) of Section 2.4 indicates that if diffusion coefficients are not equal or if the ratio C_M/C_H is not unity, then the surface energy balance requires data about the edge gases of the boundary layer. These data are provided in special "edge tables" which precede each pressure section of the surface tables (the various sections of the surface tables are described in Section 3.1.9.3 below). The independent variables for an edge table are pressure and temperature. Dependent variables are h_{ew} and the sum $\sum z_{ie}^{*} h_i^{T_w}$.

Card No.	Columns	Format	Data	Units
4	1-8	F8.5	Pressure	atm
	9-16	F8.5	Blank	--
	17-24	8X	Blank	--
	25-33	F9.4	Temperature	(°R if negative in which case enthalpies below are Btu/lb)
	34-38	F5.3	Unequal diffusion exponent γ	--

Table 09 (continued)

Card No.	Columns	Format	Data	Units
	39-47	F9.3	Summation $\sum z^*_{ie} h_i^{T_w}$	cal/gr (Btu/lb if temperature is entered with minus sign)
	48-56	F9.3	Enthalpy of edge gases h_{ew}	cal/gr (Btu/lb if temperature is entered with minus sign)
	57-58	I2	-1 (flag signifying that this card is part of the edge gas table)	--
	59-60	2X	Blank	--
	61-66	A6	Unused	--
	67-78	2A6	Leave Blank	--
5 (etc)	Same as No. 4 for remaining entries in "edge table" for this pressure, maximum of 12 temperatures for each pressure.			

Note that although the thermochemistry codes described in Section 2.4.3 will provide data decks using °K and cal/gr, in those rare cases in which a user wishes to supply his own deck and prefers to work in °R and Btu/lb, he may do so simply by introducing a minus sign as a flag in front of the temperature entries.

The table length is limited to 5 pressure sets (it may have only 1 pressure set) with not more than 12 nor less than 3 temperature entries in each set. The series of temperature values may be different for the edge table at each pressure set. The table is organized as a series of sections, each representing one pressure and each preceding the corresponding pressure group of the surface thermochemistry deck as described below. The temperature entries within each section must be ordered, either ascending or descending. Similarly, the pressures must be ordered either ascending or descending. Decks generated by the thermochemistry programs will have been automatically ordered properly.

3.1.9.3 Surface Thermochemistry Tables

3.1.9.3.1 Description of Surface Thermochemical Tables

This table comprises a series of sections. Each section represents <u>one</u> pressure and <u>one</u> transfer coefficient value. More than one transfer coefficient

Table 09 (continued)

may be necessary if the effects of kinetics on the surface response are considered. Nondimensional ablation rate, B'_{tc}, forms the third independent variable within a given section. The table has three dependent variables: $\sum z^*_{iw} h_i^{T_w}$, h_w, and T_w.

The thermochemistry programs generate separate groups for each pressure, one at a time. All these groups together make up the surface thermochemistry deck. Within each pressure group the transfer coefficient values will be ordered. Within each transfer coefficient section, ablation rate entries need not be ordered in any particular way on the ablation rates; any necessary ordering is made automatically by the code as it reads in the data.

Users providing their own thermochemistry decks must ensure that the transfer coefficients are ordered, but the ordering may be either ascending or descending in each case. The surface thermochemistry cards are identified by a unity flag in column 58, as described in the format specification below.

The number of pressure groups may not exceed 5 (and may be only 1); the number of transfer coefficient values in each pressure group may not exceed 5 but may be only 1. If no kinetics effects are to be considered a transfer coefficient of zero is acceptable. The sequence of transfer coefficient values need not be the same in the different pressure sections. Within each transfer coefficient section the number of ablation rate entries may not exceed 25 and may not be less than 2. The series of ablation values, B'_{tc} may be unique for each section.

The °R-Btu/lb option described for the edge tables in Section 3.9.3.2 may be used for these tables also.

3.1.9.3.2 Card Formats

Card No.	Columns	Format	Data	Units
n	1-8	F8.5	Pressure	atm
	9-16	F8.5	Transfer coefficient*	lb/ft^2sec
	17-24	F8.5	Nondimensional ablation rate $\dot{m}/\rho_e u_e C_M = B'$	--
	25-33	F9.4	Surface temperature	°K (°R if negative in which case enthalpies below are Btu/lb)
...				

*Not provided by most Aerotherm thermochemistry codes.

Table 09 (concluded)

Card No.	Columns	Format	Data	Units
	34-38	F5.3	Unequal diffusion exponent γ	--
	39-47	F9.3	Summation $\sum z^*_{iw} h_i^{T_w}$	cal/gr (Btu/lb if temperature is entered with minus sign)
	48-56	F9.3	Enthalpy of wall gases h_w	cal/gr (Btu/lb if temperature is entered with minus sign)
	57-58	I2	Flag indicating surface thermochemistry table entry	--
	59-60	2X	Blank	--
	61-66	A6	Chemical symbol of surface species. (ACE and GASKET programs print such symbols arranged alphabetically and truncated from right end if necessary).	--
	67-78	E12.3	Nondimensional mechanical fail rate = $\dot{m}^*/\rho_e u_e C_M = B'_{fail}$	--
n+1	Same as Card No. n for remaining entries in this section; maximum of 25 entries in each section.			

3.1.9.4 Assembled Thermochemical Deck

Figure 3-1 shows a picture of an assembled thermochemical data deck for several pressures. The deck corresponds to repeating the input described in Sections 3.1.9.2 and 3.1.9.3 for each pressure.

The surface equilibrium data deck must be terminated by two blank cards. Output decks of the thermochemistry programs do not have such cards, and the user must supply it.

3.1.10 End of Input

The end of the input data deck is signaled by a single card with a -1 punch in columns 1 and 2.

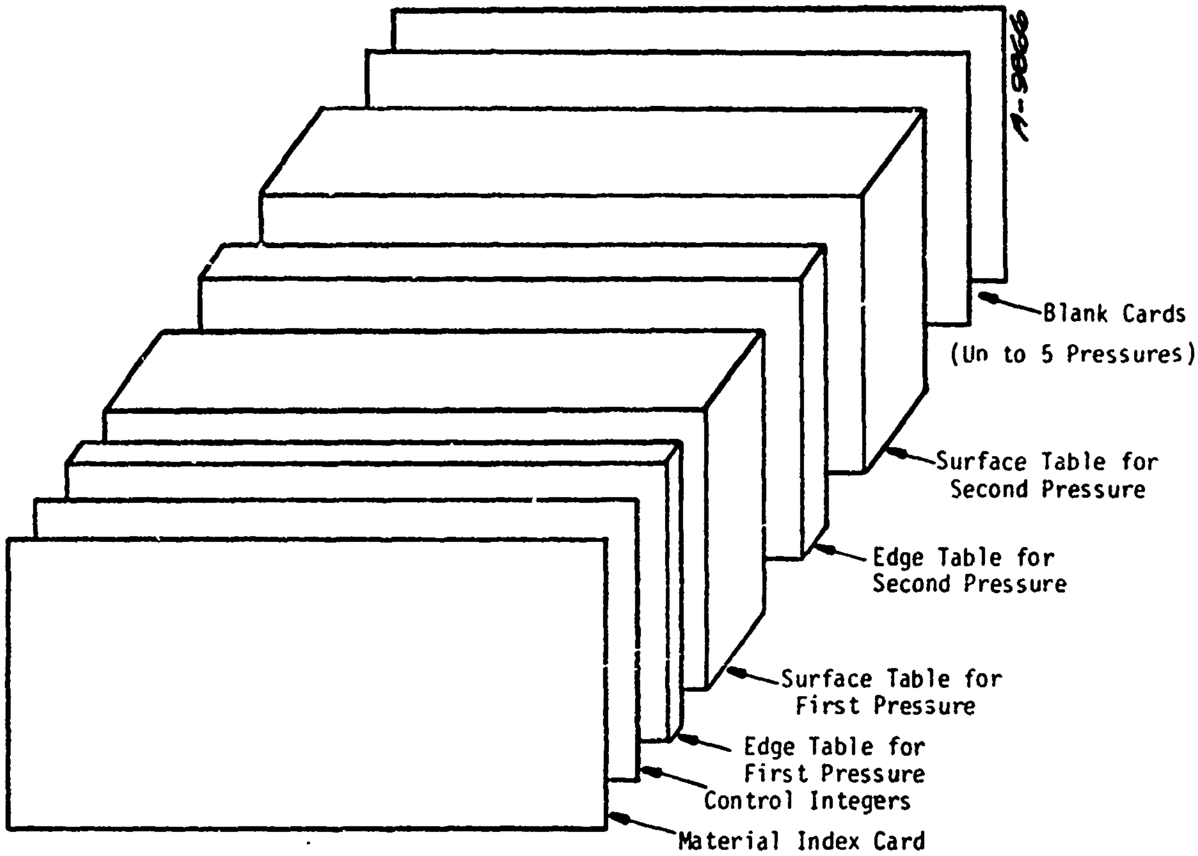


Figure 3-1. Sketch of surface thermochemistry table make-up for a given material including leading constant cards.

3.2 PROGRAM OUTPUT

The program output consists of output of the input data for check and verification purposes, and output of actual calculations. The output of the input is covered in Section 3.2.1 and the calculation output is described in Section 3.2.2.

3.2.1 Output of Input

Program output begins with an output of the restart information, and follows with the contents of input Tables 01 through 09. Most of this output is fully labeled and is printed exactly as input by the user. For those few output items not fully labeled, Appendix A provides a description.

The sensible enthalpy term output from the material properties information (Table 06) is defined as

$$h_c = HFO + \int_{TFO}^{T} C_p \, dT \qquad (3\text{-}2)$$

where

h_c = sensible enthalpy

HFO = heat of formation (input by user)

C_p = specific heat

T = temperature

The integration is performed numerically by summing over the table entries.

The surface thermochemistry table is output reordered with increasing ablation rates in each section. For each entry in the thermochemistry tables the program computes and outputs the quantity

$$TCHEM = -h_{e_w} + \frac{C_M}{C_H}\left[\sum (z_{ie}^* - z_{iw}^*) h_i^{T_w} + B'_c \left(h_c^{T_w} - h_w^{T_w}\right)\right] \qquad (3\text{-}3)$$

Notice that this term combines all of the tabular input surface thermochemistry terms and when combined with the general surface energy balance equation (Equation (2-59)) gives

$$\rho_e u_e C_H (H_r + TCHEM) - q_{cond} + \alpha_w q_{rad} - F\sigma\varepsilon_w T_w^4 = 0 \qquad (3\text{-}4)$$

The purpose for the creation of the TCHEM term is to reduce computer storage requirements. For the simpler case of equal diffusion and heat and mass transfer coefficients (i.e., no edge gas tables and $C_M = C_H$) the TCHEM term is redefined to be

$$TCHEM = -h_w^{T_w} + B'_{tc}\left(h_c^{T_w} - h_w^{T_w}\right) \qquad (3\text{-}5)$$

and Equation (3-4) is still applicable.

3.2.2 Calculation Output

Two types of calculation results are output, they are the environment calculation and the surface energy balance/in-depth calculations. The environment output is discussed in Section 3.2.2.1 and the surface energy balance and in-depth output is covered in Section 3.2.2.2.

3.2.2.1 Environment Output

The environment output consists of six tables which may be called according to the procedure given in Section 3.1. The following paragraphs give a brief description of each of these tables and the sample problem (Section 4) shows typical output.

Table 1 - Summary Information

Table 1 contains a summary of current geometry, trajectory and state variable values. This table is especially useful as a quick check on the current nose radius, stagnation point state, and stagnation point recession. Also included are the transition and sonic point locations, free stream Mach number, and number of calls to the environment and conduction packages (these are equal for the steady state option). For the flight option, the current value of altitude is given.

Table 2 - Summary Distribution

Table 2 is essentially a selective condensation of Tables 3, 4, 5, and 6. Table 2 contains current body geometry, edge pressure ratio, and Mach number distributions. Also included are heat transfer coefficient distributions and the momentum thickness Reynolds number distribution. The LAM flag output in Table 2 indicates the boundary layer flow regime and has the following three values:

- 1 - laminar flow
- 0 - transitional flow
- -1 - fully turbulent flow

Table 2 finds its major application in cases where it is desired to keep the amount of printout to a minimum. This is particularly useful when a large number of output intervals is expected, and minimum output is sufficient.

Table 3 - Entropy Swallowing Information

Table 3 contains the current body geometry, shock shape, and the entropy swallowing distribution.

Table 4 - Boundary Conditions

Table 4 shows the computed distributions along the body of boundary layer edge properties and recovery and wall conditions. Included in Table 4 (and in Tables 5 and 6) is the NTB or transition flag. This flag has four values indicating the flow regime at a given integration point. These are:

- -1 - laminar flow
- 0 - onset of transition
- 1 - transitional
- 2 - fully turbulent flow

Table 5 - Heat Transfer and Boundary Layer Quantities

Table 5 displays distributions of heat transfer coefficients, heating parameters and heat flux. Momentum and displacement thickness and laminar momentum Reynolds number distributions are also tabulated.

Table 6 - Roughness Heating Quantities

Table 6 gives distributions of laminar, turbulent (augmented and smooth), and transitional Stanton numbers. Other useful entries include distributions of surface roughness height, both transition parameters $(Re_k(s/\delta^*)^{1/3}$ and

$$Re_\theta \left(\frac{k}{\theta}\frac{T_e}{T_w}\right)^{0.7}$$

the turbulent heating augmentation parameter, and the net (laminar and turbulent) heating augmentation factor.

3.2.2.2 Surface Energy Balance and In-Depth Output

Following the environment output comes the in-depth and surface energy balance output in that order. The in-depth output consists of time step information, current nosetip material configuration, and temperature distribution. The time step information gives the size of the various controlling time steps (see Section 2.3.4), the current conduction iteration, and problem time.

Since, typically, more conduction time steps are required than environment time steps the temperature arrays are output only for the last conduction time step preceding an environment call. The time step information is output for every conduction time step. For the steady-state conduction option no in-depth output is required or given.

The surface energy balance and new body point location output is the final output prior to the next environment call. The output consists of:

- New body point locations.
- Surface temperature.
- Recession rate (both thermochemical and erosion).
- Nondimensional ablation rate (B').
- Crater roughness height.
- Surface heat flux.
- Heat transfer coefficient (both blown and nonblown).

For the transient conduction option these outputs represent the results of the last conduction time step preceding the environment call. For the steady state conduction option the output applies over the entire time step between environment calls.

SECTION 4

SAMPLE PROBLEMS

Sample Problem No. 1

Sample Problem No. 1 is a steady state wind tunnel prediction of an 8° sphere cone camphor model with a 1.5-inch nose radius.

This problem is typical of a low temperature ablator (LTA) test. It demonstrates the generality of the material and thermochemistry input, as well as the variable time step output and environment input operations. The initial shape is code-generated by implementing the sphere-cone option. Also incorporated is the stability controlled time step option.

```
    0  0
 C   INPUT DATA
     SHAPE CHANGE ANALYSIS CF 1.5 INCH NOSE RADIUS CAMPHOR MODEL
     IN WIND TUNNEL AT A FREE STREAM UNIT REYNOLDS NO OF 10*10**6/FT
       NEW ROUGH WALL TRANSITION AND HEATING EMPLOYED          RUN 207
01
  0.          70.       1.          .1
 -4  2  2  2  1  2  4  2
  2.0         30.
02
     0.0           786.          989.      1.4           5.
     150.           786.         989.
03
   20   15   .125       .75           8.0      750.0     1
06
  1  64.2   750.      0.0        0.5        0.2
  1

  1  .00096     .0022
    460.       .25        .02        1.
 41 1460.      .25        .02        1.
09
     1
     1    1.
   4.00                  -540.                        1.0  -1
   4.00                  -576.                        9.6  -1
   4.00                  -612.                       18.3  -1
   4.00                  -648.                       26.9  -1
   4.00                  -684.                       35.6  -1
   4.00                  -720.                       44.3  -1
   4.00                  -756.                       53.0  -1
   4.00                  -792.                       61.8  -1
   4.00                  -828.                       70.5  -1
   4.0000   .00000   .00034-530.0010 .000    .000  156.000 1  CAMPHOR   .000
   4.0000   .00000   .00076-550.0010 .000    .000  164.000 1  CAMPHOR   .000
   4.0000   .00000   .00160-570.0010 .000    .000  172.000 1  CAMPHOR   .000
   4.0000   .00000   .00318-590.0010 .000    .000  180.000 1  CAMPHOR   .000
   4.0000   .00000   .00606-610.0010 .000    .000  188.000 1  CAMPHOR   .000
   4.0000   .00000   .01109-630.0010 .000    .000  196.000 1  CAMPHOR   .000
   4.0000   .00000   .01957-650.0010 .000    .000  204.000 1  CAMPHOR   .000
   4.0000   .00000   .03342-670.0010 .000    .000  212.000 1  CAMPHOR   .000
   4.0000   .00000   .05542-690.0010 .000    .000  220.000 1  CAMPHOR   .000
   4.0000   .00000   .08953-710.0010 .000    .000  228.000 1  CAMPHOR   .000
   4.0000   .00000   .14141-730.0010 .000    .000  236.000 1  CAMPHOR   .000
   4.0000   .00000   .21909-750.0010 .000    .000  244.000 1  CAMPHOR   .000
   4.0000   .00000   .33423-770.0010 .000    .000  252.000 1  CAMPHOR   .000
   4.0000   .00000   .50421-790.0010 .000    .000  260.000 1  CAMPHOR   .000
   4.0000   .00000   .75610-810.0010 .000    .000  268.000 1  CAMPHOR   .000
   4.0000   .00000   .88892-818.0000 .000    .000  271.200 1  CAMPHOR   .000
   4.0000   .00000   .90724-818.0000 .000    .000  268.349 1  CAMPHOR   .183-01
   4.0000   .00000   .93871-818.0000 .000    .000  263.711 1  CAMPHOR   .498-01
   4.0000   .00000  1.02426-818.0000 .000    .000  252.543 1  CAMPHOR   .135-00
   4.0000   .00000  1.25680-818.0000 .000    .000  224.869 1  CAMPHOR   .368-00
   4.0000   .00000  1.88892-818.0000 .000    .000  196.448 1  CAMPHOR   .100+01
   4.0000   .00000  3.50720-818.0000 .000    .000  164.796 1  CAMPHOR   .272+01
```

```
4.0000  .00000 8.27798-818.0000 .000    .000  145.163 1  CAMPHOR    .739+01
4.0000  .0000020.97486-818.0000 .000    .000  135.904 1  CAMPHOR    .201+02
1.00              -540.                         1.0  -1
1.00              -576.                         9.6  -1
1.00              -612.                        18.3  -1
1.00              -612.                        18.3  -1
1.00              -648.                        26.9  -1
1.00              -684.                        35.6  -1
1.00              -720.                        44.3  -1
1.00              -756.                        53.0  -1
1.00              -792.                        61.8  -1
1.00              -792.                        61.8  -1
1.00              -828.                        70.5  -1
1.0000  .00000  .00137-530.0010 .000    .000  156.000 1  CAMPHOR    .000
1.0000  .00000  .00137-530.0010 .000    .000  156.000 1  CAMPHOR    .000
1.0000  .00000  .00305-550.0010 .000    .000  164.000 1  CAMPHOR    .000
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1.0000  .00000  .02433-610.0010 .000    .000  188.000 1  CAMPHOR    .000
1.0000  .00000  .04465-630.0010 .000    .000  196.000 1  CAMPHOR    .000
1.0000  .00000  .07917-650.0010 .000    .000  204.000 1  CAMPHOR    .000
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1.0000  .00000 7.23937-818.0000 .000    .000  270.843 1  CAMPHOR    .183-01
1.0000  .00000 7.27084-818.0000 .000    .000  270.233 1  CAMPHOR    .495-01
1.0000  .00000 7.35639-818.0000 .000    .000  268.602 1  CAMPHOR    .135-00
1.0000  .00000 7.35639-818.0000 .000    .000  268.602 1  CAMPHOR    .135-00
1.0000  .00000 7.58893-818.0000 .000    .000  264.355 1  CAMPHOR    .368-00
1.0000  .00000 8.22105-818.0000 .000    .000  254.025 1  CAMPHOR    .100+01
1.0000  .00000 9.43933-818.0000 .000    .000  232.584 1  CAMPHOR    .272+01
1.0000  .0000014.61011-818.0000 .000    .000  199.788 1  CAMPHOR    .739+01
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0.30              -540.                         1.0  -1
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0.30              -648.                        26.9  -1
0.30              -684.                        35.6  -1
0.30              -720.                        44.3  -1
0.30              -756.                        53.0  -1
0.30              -792.                        61.8  -1
0.30              -828.                        70.5  -1
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 .3000  .00000  .08198-610.0010 .000    .000  188.000 1  CAMPHOR    .000
```

```
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 .3000  .0000020,69005-770,0010 .000     .000  252.000 1  CAMPHOR    .000
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0.10                  -540.                      1.0  -1
0.10                  -576.                      9.6  -1
0.10                  -612.                     18.3  -1
0.10                  -648.                     26.9  -1
0.10                  -684.                     35.6  -1
0.10                  -720.                     44.3  -1
0.10                  -756.                     53.0  -1
0.10                  -792.                     61.8  -1
0.10                  -828.                     70.5  -1
 .1000  .00000  .01378-530,0010 .000     .000  156.000 1  CAMPHOR    .000
 .1000  .00000  .03063-550,0010 .000     .000  164.000 1  CAMPHOR    .000
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 .1000  .00000  .13029-590,0010 .000     .000  180.000 1  CAMPHOR    .000
 .1000  .00000  .25385-610,0010 .000     .000  188.000 1  CAMPHOR    .000
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 .1000  .00000 3.76569-690,0010 .000     .000  220.000 1  CAMPHOR    .000
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0.01                  -576.                      9.6  -1
0.01                  -612.                     18.3  -1
0.01                  -648.                     26.9  -1
0.01                  -684.                     35.6  -1
0.01                  -720.                     44.3  -1
0.01                  -756.                     53.0  -1
0.01                  -792.                     61.8  -1
0.01                  -828.                     70.5  -1
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 .0100  .00000  .32323-350,0010 .000     .000  164.000 1  CAMPHOR    .000
 .0100  .00000  .72618-570,0010 .000     .000  172.000 1  CAMPHOR    .000
 .0100  .00000 1.67724-590,0010 .000     .000  180.000 1  CAMPHOR    .000
 .0100  .00000 4.49182-610,0010 .000     .000  188.000 1  CAMPHOR    .000
 .0100  .0000028,14280-630,0010 .000     .000  196.000 1  CAMPHOR    .000

-1
C   END OF INPUT DATA
```

```
SHAPE CHANGE ANALYSIS OF 1.5 INCH NOSE RADIUS CAMPHOR MODEL
IN WIND TUNNEL AT A FREE STREAM UNIT REYNOLDS NO OF 10*10**6/FT
  NEW ROUGH WALL TRANSITION AND HEATING EMPLOYED          RUN 207

                    ***GENERAL PROGRAM CONSTANTS***

          (TRANSITION CRITERIA CONTROL)               TC  = -4
          (ENVIRONMENT CRITERIA CONTROL)              ENV =  2
          (CURVE FIT CONTROL)                          CF =  2
          (MATERIAL CONSTANT)                          MC =  2
          (NO. OF TIME INTERVAL CHANGES)             NTIC =  1
          (STEADY STATE FLAG)                         ISS =  2
          (OUTPUT PRINT CONTROL)                    IPRNT =  4
          (INTERMEDIATE TIME PRINT CONTROL)         LPRNT =  2

                    ***TIME INCREMENT INFORMATION***

INITIAL TIME (SEC)  0.0000              FINAL TIME (SEC) 70.0000

OUTPUT INTERVAL =  1.0000 SEC FROM INITIAL TIME UNTIL 30.0000 SEC
OUTPUT INTERVAL =  2.0000 SEC FROM  30.0000 SEC UNTIL FINAL TIME

TIME STEP STABILITY CRITERIA IN EFFECT
MINIMUM TIME STEP =1.0000E-01SECONDS
CTF =  1.300             STRD = 75.000

                    ***WIND TUNNEL ENVIRONMENT***

     GAMMA = 1.40      FREESTREAM MACH NO =  5.00

     TIME           TOTAL PRESSURE    TOTAL TEMPERATURE
     (SEC)              (PSIA)               (F)
     0.000              786.00              989.00
   150.000              786.00              989.00

          AEROTHERM NOSE TIP ANALYSIS PROCEDURE (ENDS)
```

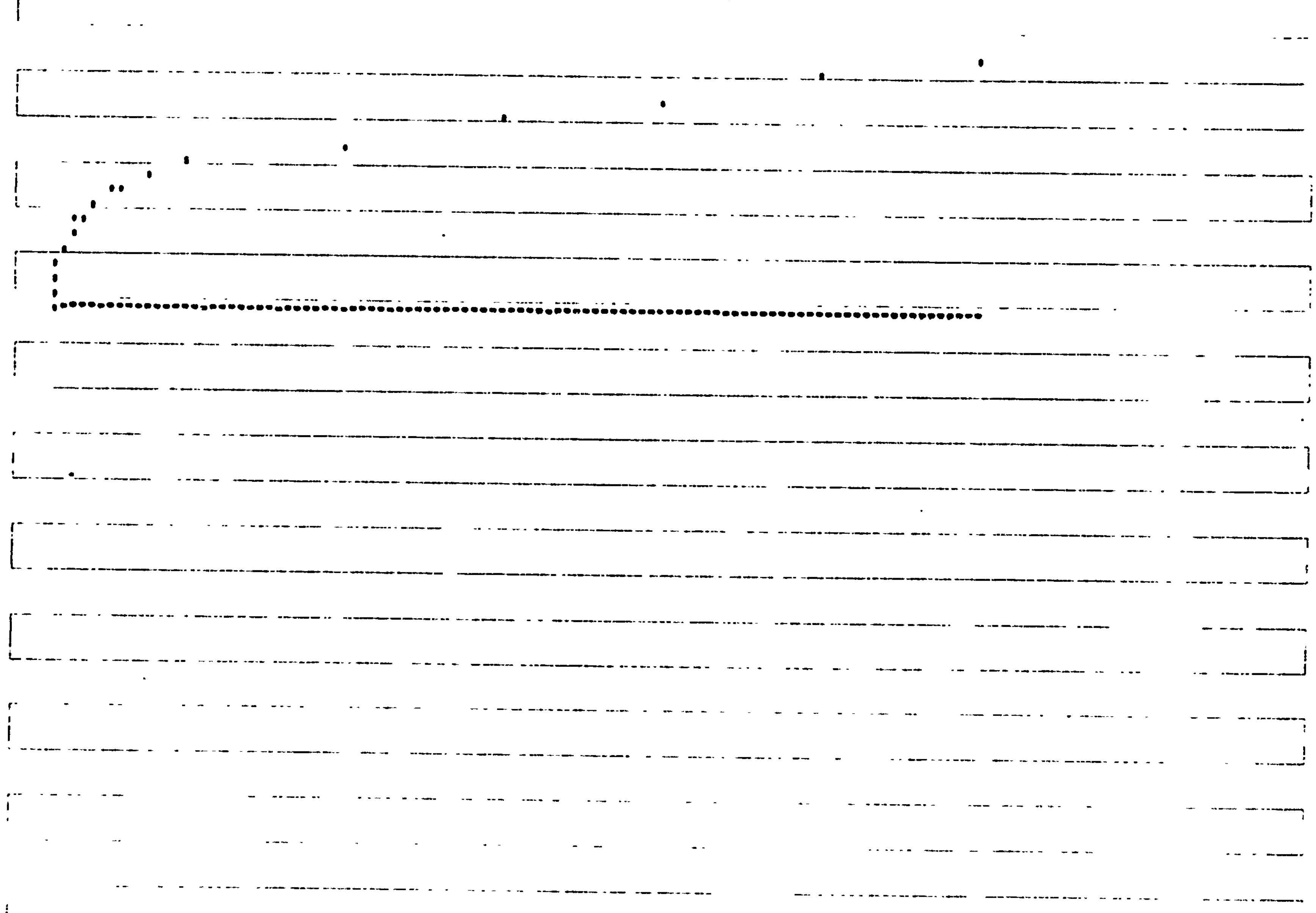
INITIAL GEOMETRY---

SPHERE CONE OPTION = GENERATED SHAPE

INITIAL NOSE RADIUS = 1,5000 INCHES
CONE ANGLE = 8,0000 DEGREES
MAXIMUM *Z* = 9,0000 INCHES

I	ZOUT	ROUT	SLOP
1	0,00000	0,00000	90,00000
			87,96938
2	,00376	,10610	85,93876
			83,90301
3	,01509	,21220	81,86726
			79,80797
4	,03416	,31830	77,74867
			75,65665
5	,06129	,42440	73,56462
			71,42642
6	,09694	,53050	69,28822
			67,08775
7	,14179	,63660	64,88727
			62,60434
8	,19678	,74270	60,32141
			57,92943
9	,26326	,84880	55,53745
			52,99931
10	,34321	,95490	50,46118
			47,72137
11	,43968	1,06100	44,98156
			41,94878
12	,55773	1,16710	38,91600
			35,41724
13	,70693	1,27320	31,91848
			27,53017
14	,91049	1,37930	23,14186
			18,59100
15	1,29124	1,48540	14,04014
			11,02007
16	2,83299	1,70208	8,00000
			8,00000
17	4,37474	1,91876	8,00000
			8,00000
18	5,91650	2,13544	8,00000
			8,00000
19	7,45825	2,35212	8,00000
			8,00000
20	9,00000	2,56880	8,00000

INITIAL SHAPE PLOT



AEROTHERM NOSE TIP ANALYSIS PROCEDURE (ENOS)

MATERIAL PROPERTIES

******* M A T E R I A L   N U M B E R   1 *******

SURFACE ROUGHNESS

ROUGHNESS HEIGHT FOR LAMINAR HEATING AND TRANSITION K-LAM = .00096 (INCH)
ROUGHNESS HEIGHT FOR TURBULENT HEATING K-TURB = .00220 (INCH)

FLAG FOR TYPE OF ROUGH TURBULENT HEATING JROUGH = 1

THERMAL PROPERTIES

RHO = 64.20
TFO = 750.00
HFO = 0.00
TBRPL = .50
TBRPT = .20

TEMPERATURE (DEG R)	SPECIFIC HEAT (BTU/LB-DEG)	CONDUCTIVITY (BTU/FT-SEC-DEG)	SENSIBLE ENTHALPY (BTU/LB)	EMISSIVITY
460.00	.2500	.0200000	-72.50	1.0000
1460.00	.2500	.0200000	177.50	1.0000

---SURFACE EQUILIBRIUM DATA---

MAT = 1
NBPF = 1
CMH = 1,0000[illegible]

P = 4,0000 ATM

TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL	TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL	TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL
540,00	1,00	648,00	26,90	756,00	53,00
576,00	9,60	684,00	35,60	792,00	61,80
612,00	18,30	720,00	44,30	828,00	70,50

M-DOT-GAS/CM = 0,0000 PRESSURE = 4,0000 ATM

TEMP	BPRIM	HCH	TSEN	HZW	HE	HZ	TCHEM	SPECIE
530,0010	,0003	-54,9997	156,0000	0,0000	-1,3886	-0,0000	1,3169	CAMP
550,0010	,0008	-49,9997	164,0000	0,0000	3,3891	0,0000	-3,5518	CAMP
570,0010	,0016	-44,9997	172,0000	0,0000	8,1669	0,0000	-8,5141	CAMP
590,0010	,0032	-39,9997	180,0000	0,0000	12,9836	0,0000	-13,6832	CAMP
610,0010	,0061	-34,9997	188,0000	0,0000	17,8169	0,0000	-19,1683	CAMP
630,0010	,0111	-29,9997	196,0000	0,0000	22,6002	0,0000	-25,1066	CAMP
650,0010	,0196	-24,9997	204,0000	0,0000	27,3836	0,0000	-31,8651	CAMP
670,0010	,0334	-19,9997	212,0000	0,0000	32,2169	0,0000	-39,9703	CAMP
690,0010	,0554	-14,9997	220,0000	0,0000	37,0502	0,0000	-50,0739	CAMP
710,0010	,0895	-9,9997	228,0000	0,0000	41,8836	0,0000	-63,1917	CAMP
730,0010	,1414	-4,9997	236,0000	0,0000	46,7169	0,0000	-80,7967	CAMP
750,0010	,2191	,0003	244,0000	0,0000	51,5502	0,0000	-105,0081	CAMP
770,0010	,3342	5,0003	252,0000	0,0000	56,4225	0,0000	-138,9772	CAMP
790,0010	,5042	10,0003	260,0000	0,0000	61,3114	0,0000	-187,3637	CAMP
810,0010	,7561	15,0003	266,0000	0,0000	66,1502	0,0000	-257,4434	CAMP
818,0000	,8889	17,0000	271,2000	0,0000	68,0833	0,0000	-294,0468	CAMP
818,0000	,9072	17,0000	268,3490	0,0000	68,0833	0,0000	-296,1172	CAMP
818,0000	,93[illegible]7	17,0000	263,7110	0,0000	68,0833	0,0000	-299,6734	CAMP
818,0000	1,02[illegible]3	17,0000	252,5430	0,0000	68,0833	0,0000	-309,3406	CAMP
818,0000	1,2568	17,0000	229,8690	0,0000	68,0833	0,0000	-335,6171	CAMP
818,0000	1,8869	17,0000	196,4480	0,0000	68,0833	0,0000	-407,0462	CAMP
818,0000	3,6072	17,0000	164,7960	0,0000	68,0833	0,0000	-601,2131	CAMP
818,0000	8,2780	17,0000	145,1630	0,0000	68,0833	0,0000	-1129,0141	CAMP
818,0000	20,9745	17,0000	135,9840	0,0000	68,0833	0,0000	-25[illegible]3,7085	CAMP

P = 1.0000 ATM

TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL	TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL	TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL
540.00	1.00	648.00	26.90	756.00	53.00
576.00	9.60	684.00	35.60	792.00	61.80
612.00	18.30	720.00	44.30	828.00	70.50

M-DOT-GAS/CM = 0.0000 PRESSURE = 1.0000 ATM

TEMP	BPRIM	HCH	TSEN	HZW	HE	HZ	TCHEM	SPECIE
530.0010	.0018	-54.9997	156.0000	0.0000	-1.3886	-0.0000	1.0996	CAMP
550.0010	.0030	-49.9997	164.0000	0.0000	3.3891	0.0000	-4.0418	CAMP
570.0010	.0064	-44.9997	172.0000	0.0000	8.1669	0.0000	-9.5535	CAMP
590.0010	.0127	-39.9997	180.0000	0.0000	12.9836	0.0000	-15.7864	CAMP
610.0010	.0243	-34.9997	188.0000	0.0000	17.8169	0.0000	-23.2425	CAMP
630.0010	.0447	-29.9997	196.0000	0.0000	22.6002	0.0000	-32.6911	CAMP
650.0010	.0792	-24.9997	204.0000	0.0000	27.3836	0.0000	-45.5135	CAMP
670.0010	.1363	-19.9997	212.0000	0.0000	32.2169	0.0000	-63.8338	CAMP
690.0010	.2289	-14.9997	220.0000	0.0000	37.0502	0.0000	-90.8417	CAMP
710.0010	.3778	-9.9997	228.0000	0.0000	41.8836	0.0000	-131.7098	CAMP
730.0010	.6153	-4.9997	236.0000	0.0000	46.7169	0.0000	-195.0065	CAMP
750.0010	1.0017	.0003	244.0000	0.0000	51.5502	0.0000	-295.9550	CAMP
770.0010	1.6522	5.0003	252.0000	0.0000	56.4225	0.0000	-464.5253	CAMP
790.0010	2.8323	10.0003	260.0000	0.0000	61.3118	0.0000	-769.3806	CAMP
810.0010	5.3224	15.0003	268.0000	0.0000	66.1502	0.0000	-1412.7035	CAMP
818.0000	7.3210	17.0000	271.2000	0.0000	68.0833	0.0000	-1903.6742	CAMP
818.0000	7.2398	17.0000	270.8430	0.0000	68.0833	0.0000	-1905.7467	CAMP
818.0000	7.2708	17.0000	270.2330	0.0000	68.0833	0.0000	-1909.3000	CAMP
818.0000	7.3568	17.0000	268.6020	0.0000	68.0833	0.0000	-1918.9658	CAMP
818.0000	7.5889	17.0000	264.3550	0.0000	68.0833	0.0000	-1945.2431	CAMP
818.0000	8.2210	17.0000	254.0250	0.0000	68.0833	0.0000	-2016.6777	CAMP
818.0000	9.9393	17.0000	232.5840	0.0000	68.0833	0.0000	-2210.5839	CAMP
818.0000	14.6101	17.0000	199.7880	0.0000	68.0833	0.0000	-2738.6361	CAMP
818.0000	27.3066	17.0000	167.3390	0.0000	68.0833	0.0000	-4173.3288	CAMP

P = .3000 ATM

TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL	TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL	TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL
540.00	1.00	648.00	26.90	756.00	53.00
576.00	9.60	684.00	35.60	792.00	61.80
612.00	18.30	720.00	44.30	828.00	70.50

M-DOT-GAS/CM = 0.0000   PRESSURE = .3000 ATM

TEMP	BPRIM	HCH	TSEN	HZW	HE	HZ	TCHEM	SPECIE
530.0010	.0046	-54.9997	156.0000	0.0000	-1.3886	-0.0000	.4202	CAMP
550.0010	.0102	-49.9997	164.0000	0.0000	3.3891	0.0000	-5.5655	CAMP
570.0010	.0213	-44.9997	172.0000	0.0000	8.1669	0.0000	-12.7999	CAMP
590.0010	427	-39.9997	180.0000	0.0000	12.9836	0.0000	-22.3820	CAMP
610.0010	1820	-34.9997	188.0000	0.0000	17.8169	0.0000	-36.0984	CAMP
630.0010	.1518	-29.9997	196.0000	0.0000	22.6002	0.0000	-56.9160	CAMP
650.0010	.2735	-24.9997	204.0000	0.0000	27.3836	0.0000	-90.0173	CAMP
670.0010	.4835	-19.9997	212.0000	0.0000	32.2169	0.0000	-144.3934	CAMP
690.0010	.8494	-14.9997	220.0000	0.0000	37.0502	0.0000	-236.6520	CAMP
710.0010	1.5114	-9.9997	228.0000	0.0000	41.8836	0.0000	-401.6012	CAMP
730.0010	2.8223	-4.9997	236.0000	0.0000	46.7169	0.0000	-726.8977	CAMP
750.0010	6.0146	.0003	244.0000	0.0000	51.5502	0.0000	-1519.1018	CAMP
770.0010	20.6901	5.0003	252.0000	0.0000	56.4225	0.0000	-5166.8596	CAMP

P = .1000 ATM

TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL	TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL	TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL
540.00	1.00	648.00	26.90	756.00	53.00
576.00	9.60	684.00	35.60	792.00	61.80
612.00	18.30	720.00	44.30	828.00	70.50

M-DOT-GAS/CM = 0.0000   PRESSURE = .1000 ATM

TEMP	BPRIM	HCH	TSEN	HZW	HE	HZ	TCHEM	SPECIE
530.0010	.0138	-54.9997	156.0000	0.0000	-1.3886	-0.0000	-1.5189	CAMP
550.0010	.0306	-49.9997	164.0000	0.0000	3.3891	0.0000	-9.9439	CAMP
570.0010	.0646	-44.9997	172.0000	0.0000	8.1669	0.0000	-22.1807	CAMP
590.0010	.1303	-39.9997	180.0000	0.0000	12.9836	0.0000	-41.6473	CAMP
610.0010	.2538	-34.9997	188.0000	0.0000	17.8169	0.0000	-74.4254	CAMP
630.0010	.4835	-29.9997	196.0000	0.0000	22.6002	0.0000	-131.8621	CAMP
650.0010	.9159	-24.9997	204.0000	0.0000	27.3836	0.0000	-237.1244	CAMP
670.0010	1.7778	-19.9997	212.0000	0.0000	32.2169	0.0000	-444.6614	CAMP
690.0010	3.7657	-14.9997	220.0000	0.0000	37.0502	0.0000	-921.9865	CAMP
710.0010	10.6782	-9.9997	228.0000	0.0000	41.8836	0.0000	-2583.2996	CAMP

P = .0100 ATM

TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL	TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL	TEMPERATURE (DEG R)	EDGE ENTH AT T-WALL
540.00	1.00	648.00	26.90	756.00	53.00
576.00	9.60	684.00	35.60	792.00	61.80
612.00	18.30	720.00	44.30	828.00	70.50

M=DOT-GAS/CM = 0,0000 PRESSURE = ,0100 ATM

TEMP	BPRIM	HCH	TSEN	HZW	HE	HZ	TCHEM	SPECIE
530,0010	,1411	-54,9997	156,0000	0,0000	-1,3686	-0,0000	-28,3897	CAMP
550,0010	,3232	-49,9997	164,0000	0,0000	3,3891	0,0000	-72,5603	CAMP
570,0010	,7262	-44,9997	172,0000	0,0000	8,1669	0,0000	-165,7478	CAMP
590,0010	1,6772	-39,9997	180,0000	0,0000	12,9836	0,0000	-381,9760	CAMP
610,0010	4,4918	-34,9997	188,0000	0,0000	17,8169	0,0000	-1019,4916	CAMP
630,0010	28,1428	-29,9997	196,0000	0,0000	22,6002	0,0000	-6382,5660	CAMP

*** OVERLAY(3,0) //ENVIRT *** . . . .

*** OVERLAY(3,1) //VORTI *** . . . .

SHOULDER POINT = 16 SONIC POINT = 12

*** STAGNATION POINT ENVIRONMENT HISTORY FOR THE INITIAL BODY SHAPE ***

TIME (SEC)	PRESSURE (ATM)	ENTHALPY (BTU/LBM)	HEAT TRANS,COEFF, (LBM/FT2-SEC)	VELOCITY (FT/SEC)	DENSITY (LBM/FT3)	PRESSURE (ATM)
	* *STAGNATION POINT QUANTITIES* *			* *FREESTREAM QUANTITIES* *		
0,0000	3,294E+00	3,476E+02	1,980E-01	3,808E+03	1,660E-02	1,011E-01
150,0000	3,294E+00	3,476E+02	1,980E-01	3,808E+03	1,660E-02	1,011E-01

*** OVERLAY(3,0) //ENVIRT *** . . . .

*** OVERLAY(3,2) //VORTIS *** . . . .

NEW CURVE FIT DONE TO BODY POINTS
8CURVES FIT TO, 23 POINTS

AEROTHERM NOSE TIP ANALYSIS PROCEDURE (ENOS)

CURVE	A	B	C	AUC(I+1)
1	-30.68329E+03	17.60692E+03	52.80612E-17	48.68748E-04
2	-32.39197E+03	17.62356E+03	-40.50374E-03	98.44675E-04
3	97.44385E+02	16.79392E+03	90.43251E-01	14.83550E-03
4	21.69808E+02	17.01867E+03	23.76147E-01	19.81830E-03
5	39.41422E+02	16.94845E+03	30.71975E-01	26.58305E-03
6	87.37623E+02	16.69345E+03	64.61252E-01	31.53476E-03
7	12.56550E+03	16.45203E+03	10.26785E+00	36.44990E-03
8	-73.98213E+01	17.42199E+03	-74.09537E-01	40.37134E-03

*** OVERLAY(3,3) //VORTS ***

AEROTHERM NOSE TIP ANALYSIS PROCEDURE (ENOS)

**************************************O U T P U T *** TIME= 0.00 SEC

****
* VURT CALLED AT FIRST TIME STEP *
****

TABLE-1 SUMMARY INFORMATION

ITERATION NO. ITS	ITERATION NO. ITS	TIMEP (SEC)	ALTITUDE ALT (FT)	FREESTREAM MACH-NO. M-INF	PT. STAGNATION PRESSURE PT2 (ATM)	PT. STAGNATION ENTHALPY HO (BTU/LBM)
1	0	0.0000	1	5.000	3.2980	347.6

STAG. PT. RECESSION SPREC (INCH)	CURRENT NOSE RADIUS RN (INCH)	EFFECTIVE NOSE RADIUS R-EFF (INCH)	STAGNATION PT. HEAT TRANS. COEF. SPHTC (LBM/FT**2-SEC)	TRANSITION STREAM LENGTH S-TRAN (INCH)	SONIC PT. AXIAL LENGTH X-STAR (INCH)	SONIC PT. RADIAL LENGTH Y-STAR (INCH)
0.0000	1.4973	1.4772	.1918	.4973	.3879	1.0041

TABLE-3 ENTROPY SWALLOWING INFORMATION

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, L = SHOCK POINT INDEX,
K = SHOCK POINT INDEX FOR STREAMLINE ENTRAINED IN BOUNDARY LAYER AT INTEGRATION POINT I

			* * * * * * * BODY GEOMETRY * * * * * * * *					* * * * * * SHOCK SHAPE * * * * * *					* ENTROPY SWALLOWING *	
J	I	K	STREAM LENGTH S (INCH)	AXIAL LENGTH X (INCH)	RADIAL LENGTH Y (INCH)	S OVER INPUT RADIUS S/R	BODY ANGLE (DEG)	L	SHOCK AXIAL LENGTH X-SHOCK (INCH)	SHOCK RADIAL LENGTH Y-SHOCK (INCH)	SHOCK ANGLE BETA (DEG)	ENTROPY BEHIND SHOCK SRB	SWALLOWING PARAMETER YBAR (INCH)	EDGE ENTROPY ENTR
1	1	1	0.0000	0.0000	0.0000	0.0000	90.00	1	-.2278	0.0000	90.00	26.051	.0024	26.051
2	6	1	.1062	.0038	.1061	.0708	85.92	6	-.2230	.1222	86.18	26.041	.0073	26.051
3	11	1	.2129	.0151	.2122	.1419	81.87	11	-.2099	.2443	82.36	26.008	.0145	26.051
4	16	1	.3207	.0342	.3183	.2138	77.75	16	-.1884	.3666	78.57	25.955	.0217	26.051
5	21	2	.4302	.0613	.4244	.2868	73.56	21	-.1586	.4893	74.81	25.885	.0288	26.051
6	26	3	.5421	.0969	.5305	.3618	69.29	26	-.1198	.6124	71.02	25.797	.0642	26.048
7	31	5	.6573	.1418	.6366	.4382	64.89	31	-.0717	.7367	67.41	25.700	.1035	26.043
8	36	6	.7768	.1968	.7427	.5179	60.32	36	-.0133	.8624	63.57	25.586	.1418	26.036
9	41	8	.9020	.2633	.8488	.6013	55.54	41	.0568	.9905	59.82	25.467	.1873	26.026
10	46	10	1.0349	.3432	.9549	.6899	50.46	46	.1408	1.1220	55.77	25.336	.2281	26.015
11	51	11	1.1783	.4397	1.0610	.7855	44.98	51	3620	1.4342	53.66	25.269	.2660	26.001
12	56	13	1.3370	.5577	1.1671	.8913	38.92	56	[illegible]455	1.7810	45.9[illegible]	25.030	.3007	25.987
13	61	14	1.5201	.7069	1.2732	1.0134	31.92	61	1.1213	2.2129	37.77	24.390	.3307	25.974
14	63	15	1.7496	.9105	1.3793	1.1664	23.14	63	1.8325	2.7007	28.22	23.873	.3503	25.966
15	65	16	2.1449	1.2712	1.4854	1.4299	14.04	65	3.0505	3.6690	19.22	22.835	.3763	25.956
16	69	19	3.7018	2.8330	1.7021	2.4679	8.00	69	11.1348	5.9370	14.19	22.217	.4467	25.918
17	73	21	5.2587	4.3747	1.9188	3.5058	8.00	73	15.7851	7.1131	14.19	22.207	.5001	25.885
18	77	23	6.8156	5.9165	2.1354	4.5437	8.00	77	18.6064	7.8266	14.19	22.206	.5475	25.852
19	81	25	8.3725	7.4582	2.3521	5.5817	8.00	81	21.4090	8.5354	14.19	22.205	.5911	25.819
20	85	26	9.9294	9.0000	2.[illegible]688	6.6196	8.00	85	24.1762	9.2353	14.1[illegible]	22.205	.6325	25.789

TABLE-4 BOUNDARY CONDITIONS TIME= 0.00 SEC

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, NTB = TRANSITION FLAG

J	I	NTB	STREAM LENGTH S (INCH)	PRESSURE RATIO PE/PT2	EDGE MACH NO. ME	EDGE ENTHALPY HE (BTU/LBM)	EDGE TEMP TE (R)	EDGE DENSITY RHOE (LBM/FT3)	EDGE VELOCITY VEL (FT/SEC)	EDGE VISC. UE (LBM/FT-SEC)	EDGE REYNOLDS NO. RE-EDGE (1/FT)	RECOVERY TEMP. TW (R)	RECOVERY ENTHALPY HR (BTU/LBM)	WALL TEMP TW (R)	WALL ENTHALPY HW (BTU/LBM)
			-----	-----	BOUNDARY LAYER	EDGE PROPERTIES	-----	-----	-----	-----	-----	RECOVERY CONDITIONS		WALL CONDITIONS	
1	1	-1	0.0000	1.0000	0.0000	347.6	1403.8	9.303E-02	0.0	2.421E-05	0.	1403.8	347.6	750.0	181.1
2	6	-1	.1062	.9944	.0836	347.2	1401.9	9.263E-02	153.3	2.419E-05	5.873E+05	1403.5	347.6	750.0	181.1
3	11	-1	.2129	.9777	.1665	345.8	1395.5	9.145E-02	305.0	2.413E-05	1.156E+06	1402.6	347.3	750.0	181.1
4	16	-1	.3207	.9501	.2513	343.4	1387.3	8.944E-02	458.8	2.403E-05	1.708E+06	1401.2	347.0	750.0	181.1
5	21	-1	.4302	.9118	.3392	340.0	1374.1	8.666E-02	616.2	2.388E-05	2.236E+06	[illegible]	[illegible]	750.0	181.1
6	26	1	.5421	.8630	.4348	335.5	1355.7	8.314E-02	788.5	2.368E-05	2.754E+06	1397.3	346.0	750.0	181.1
7	31	1	.6573	.8044	.5371	329.6	1331.7	7.888E-02	960.5	2.332E-05	3.235E+06	1394.9	345.4	750.0	181.1
8	36	1	.7768	.7364	.6476	322.4	1301.4	7.391E-02	1145.0	2.308E-05	3.667E+06	1391.7	344.6	750.0	181.1
9	41	1	.9020	.6504	.7696	313.4	1263.4	6.827E-02	1340.7	2.265E-05	4.041E+06	1387.9	343.8	750.0	181.1
10	46	1	1.0349	.5784	.9032	302.5	1217.4	6.205E-02	1544.5	2.212E-05	4.332E+06	1383.2	342.6	750.0	181.1
11	51	1	1.1783	.4918	1.0533	289.2	1161.9	5.528E-02	1759.6	2.187E-05	4.531E+06	1377.3	341.2	750.0	181.1
12	56	1	1.3370	.3964	1.2405	271.6	1089.3	4.753E-02	2005.5	2.059E-05	4.633E+06	1369.5	339.3	750.0	181.1
13	61	1	1.5201	.2971	1.4808	248.2	994.6	3.902E-02	2259.7	1.939E-05	4.607E+06	1359.3	336.8	750.0	181.1
14	63	1	1.7496	.1504	1.8547	210.3	852.4	2.764E-02	2653.8	1.746E-05	4.201E+06	1343.9	332.7	750.0	181.1
15	65	1	2.1449	.1169	2.1262	186.2	757.2	2.017E-02	2867.3	1.608E-05	3.598E+06	1333.6	330.1	750.0	181.1
16	69	2	3.7019	.0764	2.3926	167.2	672.3	1.444E-02	3040.5	1.476E-05	2.975E+06	1324.8	328.1	750.0	181.1
17	73	2	5.2587	.0660	2.4818	162.1	646.2	1.335E-02	3071.9	1.434E-05	2.878E+06	1322.0	327.6	750.0	181.1
18	77	2	6.8156	.0605	2.5573	158.3	624.9	1.261E-02	3133.1	1.399E-05	2.825E+06	1319.7	327.2	750.0	181.1
19	81	2	8.3725	.0561	2.6242	155.1	606.7	1.207E-02	3167.9	1.368E-05	2.795E+06	1317.7	326.6	750.0	181.1
20	85	2	9.9294	.0530	2.6810	152.7	591.8	1.170E-02	3196.3	1.343E-05	2.783E+06	1316.1	326.6	750.0	181.1

AEROTHERM NOSE TIP ANALYSIS PROCEDURE (ENOS)

TABLE-5 HEAT TRANSFER AND BOUNDARY LAYER QUANTITIES

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, NTB = TRANSITION FLAG

J	I	NTB	STREAM LENGTH S (INCH)	NON-BLOWN HEAT FLUX QDOT (BTU/FT2-SEC)	HEAT TRANS. COEF. BASED ON TR HTC (BTU/FT2-SEC-R)	HEAT TRANS. COEF. BASED ON HR CHO (LBM/FT2-SEC)	LAMINAR HEATING PARAMETER FL	TURBULENT HEATING PARAMETER FT	WEIGHTING PARAMETER FPT	NET HEATING PARAMETER FCNT	LAMINAR MOMENTUM THICKNESS THETA-LAM (MIL)	DISPLACE-MENT THICKNESS DELSTR (MIL)	LAMINAR MOMENTUM REYN. NO. RETHL
1	1	-1	0.0000	3.1950E+01	4.8870E-02	.1918	1.0000	1.0000	0.0000	1.0000	.445	.390	0.00
2	6	-1	.1062	3.1497E+01	4.8201E-02	.1892	.9863	1.0418	0.0000	.9853	.450	.396	22.03
3	11	-1	.2129	3.1003E+01	4.7504E-02	.1865	.9721	1.2485	0.0000	.9[illegible]21	.456	.403	43.89
4	16	-1	.3207	3.0343E+01	4.6595E-02	.1829	.9535	1.4955	0.0000	.9535	.463	.414	65.85
5	21	-1	.4302	2.9453E+01	4.5373E-02	.1791	.9285	1.7283	0.0000	.9285	.472	.430	88.01
6	26	1	.5421	4.3667E+01	6.7456E-02	.2648	.8958	2.2420	.4711	1.3802	.486	.452	110.46
7	31	1	.6573	5.5482E+01	8.6029E-02	.3376	.8552	2.4107	.6963	1.7599	.503	.483	133.29
8	36	1	.7768	6.2555E+01	9.7483E-02	.3824	.8069	2.5089	.7978	1.9935	.526	.525	156.67
9	41	1	.9020	7.0071E+01	1.0984E-01	.4307	.7493	2.5272	.90[illegible]	2.2452	.557	.582	180.89
10	46	1	1.0349	7.1209E+01	1.1247E-01	.4407	.6827	2.4622	.9460	2.2976	.597	.663	206.31
11	51	1	1.1783	6.7940E+01	1.0831E-01	.4242	.6106	2.3129	.9663	2.2114	.652	.778	233.62
12	56	1	1.3370	6.0889E+01	9.8293E-02	.3847	.5260	2.0695	.9771	2.0056	.729	.959	265.01
13	61	1	1.5201	5.0332E+01	8.2612E-02	.3232	.4302	1.7241	.9833	1.6847	.846	1.270	303.96
14	63	1	1.7496	3.2355E+01	5.4483E-02	.2134	.3040	1.1322	.9865	1.1123	1.097	2.039	366.14
15	65	1	2.1449	1.9250E+01	3.2986E-02	.1292	.1910	.6835	.9883	.6733	1.517	3.297	434.53
16	69	2	3.7018	1.0665E+01	1.8592E-02	.0727	.1058	.3830	.9914	.3788	2.432	6.149	562.87
17	73	2	5.2587	9.4022E+00	1.6438E-02	.0642	.0854	.3377	.9931	.3345	2.812	7.470	617.68
18	77	2	6.8156	8.5579E+00	1.5023E-02	.0586	.0754	.3079	.9940	.3053	3.123	8.645	659.94
19	81	2	8.3725	7.9824E+00	1.3990E-02	.0545	.0682	.2862	.9946	.2840	3.391	9.734	694.85
20	85	2	9.9294	7.4979E+00	1.3245E-02	.0515	.0628	.2706	.9951	.2686	3.618	10.709	724.43

AEROTHERM NOSE TIP ANALYSIS PROCEDURE (ENOS)

TABLE=6 ROUGHNESS HEATING QUANTITIES

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, NTB = TRANSITION FLAG

J	I	NTB	STREAM LENGTH S (INCH)	LAMINAR ROUGH STANT NO, STANTL	COMPOSITE ROUGH STANT NO, STANTT	COMPOSITE SMOOTH STANT NO, STANTS	TRANSITION ROUGH STANT NO, STANTN	ROUGHNESS HEIGHT K (MIL)	DELSTR TRANSITION PARAMETER	THEATA TRANSITION PARAMETER	TURBULENT ROUGHNESS HEATING PARAMETER	NET ROUGHNESS HEATING FACTOR	TURBULENT MOMENTUM REYN, NO, RETHT
1	1	-1	0,0000	0,	0,	0,	0,	,96	0,000	0,	0,	1,000	0,
2	6	-1	,1062	1,3320E-02	1,4044E-02	1,3633E-02	1,3320E-02	,96	303,046	5,8002E+01	1,2371E+01	1,000	2,6021E+01
3	11	-1	,2129	6,6873E-03	8,5616E-03	7,6286E-03	6,6[illegible]73E-03	[illegible]	747,083	1,1425E+02	1,8119E+01	1,000	6,3116E+01
4	16	-1	,3207	4,4572E-03	6,9281E-03	5,7753E-03	4,4[illegible]72E-03	,96	[illegible]254,430	1,6882E+02	2,3098E+01	1,000	1,1697E+02
5	21	-1	,4302	3,3355E-03	6,1247E-03	4,8726E-03	3,3355E-03	,96	1788,921	2,2090E+02	2,7431E+01	1,000	1,8823E+02
6	26	1	,5421	2,6305E-03	6,5316E-03	4,3155E-03	4,0592E-03	2,20	2340,682	4,8140E+02	7,1609E+01	1,242	2,7852E+02
7	31	1	,6573	2,1650E-03	6,0588E-03	3,9177E-03	4,4553E-03	2,20	2868,735	5,5549E+02	7,8315E+01	1,381	4,0767E+02
8	36	1	,7768	1,8279E-03	5,6523E-03	3,6057E-03	4,5186E-03	2,20	3343,013	6,2700E+02	8,2629E+01	1,453	5,5350E+02
9	41	1	,9020	1,5703E-03	5,2783E-03	3,3448E-03	4,7054E-03	2,20	3740,191	6,8180E+02	8,4394E+01	1,522	7,1392E+02
10	46	1	1,0349	1,3665E-03	4,9176E-03	3,1157E-03	4,5990E-03	2,20	4020,449	7,2127E+02	8,3219E+01	1,547	8,8675E+02
11	51	1	1,1783	1,2086E-03	4,5546E-03	2,9046E-03	4,3614E-03	2,20	4162,405	7,4352E+02	7,9086E+01	1,549	1,0699E+03
12	56	1	1,3370	1,0579E-03	4,1576E-03	2,6924E-03	4,0338E-03	2,20	4141,060	7,4577E+02	7,1596E+01	1,532	1,2619E+03
13	61	1	1,5201	9,2344E-04	3,7001E-03	2,4647E-03	3,6187E-03	2,20	3912,726	7,2307E+02	6,0515E+01	1,493	1,4620E+03
14	63	1	1,7496	7,9403E-04	2,9591E-03	2,1747E-03	2,9085E-03	1,87	3193,918	5,8160E+02	3,6044E+01	1,356	1,6688E+03
15	65	1	2,1449	6,3359E-04	2,2660E-03	1,9495E-03	2,2332E-03	1,32	2493,838	3,9735E+02	1,7728E+01	1,160	1,9282E+03
16	69	2	3,7018	4,6232E-04	1,6723E-03	1,5723E-03	1,6545E-03	,96	2009,765	2,7200E+02	8,4436E+00	1,000	2,5293E+03
17	73	2	5,2587	3,9605E-04	1,5692E-03	1,5692E-03	1,5550E-03	,96	2048,078	2,6226E+02	7,5143E+00	1,000	2,8641E+03
18	77	2	6,8156	3,6507E-04	1,4943E-03	1,4943E-03	1,4823E-03	,96	2087,535	2,5437E+02	6,8908E+00	1,000	3,1424E+03
19	81	2	8,3725	3,4191E-04	1,4352E-03	1,4352E-03	1,4247E-03	,96	2126,058	2,4763E+02	6,4291E+00	1,000	3,3849E+03
20	85	2	9,9294	3,2246E-04	1,3877E-03	1,3877E-03	1,3784E-03	,96	2171,241	2,4242E+02	6,0953E+00	1,000	3,6042E+03

,96000000 3,24395666 1403,78169790 4474547,688179287

*** OVERLAY(4,0) //THERMO *** •

AEROTHERM NOSE TIP ANALYSIS PROCEDURE (EROS)

BODY POINT LOCATIONS AND SURFACE ENERGY BALANCE RESULTS AT
TIME = 1.0000 SEC

* DENOTES ANGLE LIMIT

POINT NUMBER	Z (INCHES)	Z-DOT USED	WALL TEMPERATURE (DEG R)	S-DOT TOTAL (IN/SEC)	S-DOT EROSION (IN/SEC)	PARTICLE ROUGHNESS (MILS)	B-PRIME THERMO-CHEM	CHH	CH (LBM/FT**2-SEC)	CHZ
1	.01476	.01476	780.95	14.7615E-03	0.	0.	50.9392E-02	34.0501E+00	15.5036E-02	.19182
2 *	.01847	.01471	780.67	14.5608E-03	0.	0.	50.9449E-02	33.5721E+00	15.2911E-02	.18920
3	.02959	.01450	779.87	14.3561E-03	0.	0.	50.9700E-02	33.0509E+00	15.0687E-02	.18646
4	.04858	.01442	778.50	14.0920E-03	0.	0.	51.0149E-02	32.3593E+00	14.7784E-02	.18290
5	.07561	.01432	776.53	13.7374E-03	0.	0.	51.0806E-02	31.4279E+00	14.3881E-02	.17811
6	.12008	.02313	774.09	21.6398E-03	0.	0.	51.3629E-02	49.1371E+00	22.5402E-02	.26476
7	.17324	.03146	770.86	28.4833E-03	0.	0.	5 .6287E-02	64.1724E+00	29.5157E-02	.33758
8	.23458	.03780	766.77	32.8423E-03	0.	0.	51.9214E-02	73.3160E+00	33.8408E-02	.38240
9	.30904	.04578	761.78	37.7450E-03	0.	0.	52.[illegible]087E-02	83.2953E+00	38.6045E-02	.43068
10	.39399	.05078	755.58	39.1597E-03	0.	0.	52.77[illegible]9E-02	85.2076E+00	39.6993E-02	.44074
11	.49369	.05401	748.05	38.1775E-03	0.	0.	53.3668E-02	81.6069E+00	38.2728E-02	.42420
12	.61373	.05600	738.06	35.1763E-03	0.	0.	54.2202E-02	73.3530E+00	34.7091E-02	.38471
13	.76404	.05711	724.86	30.1984E-03	0.	0.	55.4786E-02	60.8008E+00	29.1175E-02	.32316
14	.96250	.05201	704.82	20.4416E-03	0.	0.	57.0100E-02	39.2688E+00	19.1831E-02	.21337
15	1.34344	.05220	687.37	12.6627E-03	0.	0.	58.4696E-02	23.4165E+00	11.5864E-02	.12916
16	2.88545	.05246	670.14	73.0055E-04	0.	0.	60.0561E-02	13.0160E+00	65.0358E-03	.07266
17	4.42136	.04662	665.96	64.8833E-04	0.	0.	60.4664E-02	11.4582E+00	57.4060E-03	.06417
18	5.95925	.04276	662.77	59.5079E-04	0.	0.	60.7792E-02	10.4331E+00	52.3809E-03	.05857
19	7.49818	.03993	660.18	55.5702E-04	0.	0.	61.0355E-02	76.8537E-01	48.7094E-03	.05048
20	9.03787	.03787	658.18	52.7107E-04	0.	0.	61.2330E-02	91.4531E-01	46.0539E-03	.05153

TOTAL STAGNATION POINT RECESSION DUE TO EROSION ONLY = 0.0000 INCHES

*** OVERLAY(3,0) //ENVIRI *** -

*** OVERLAY(3,1) //VORT1 *** -

SHOULDER POINT = 16 SONIC POINT = 12

*** OVERLAY(3,2) //VORT15 *** -

NEW CURVE FIT DONE TO BODY POINTS
/CURVES FIT TO, 22 POINTS

CURVE	A	B	C	AUC(I+1)
1	-61.34737E+02	16.71286E+03	10.18335E-17	53.07811E-04
2	-35.44596E+03	17.02401E+03	-82.57872E-02	10.69970E-03
3	86.47757E+03	14.41614E+03	13.11942E+00	16.03167E-03
4	-10.17228E+04	20.45047E+03	-35.25078E+00	23.10928E-03
5	73.69475E+03	-18.31166E+03	41.26317E+01	27.07877E-03
6	15.60394E+0[illegible]	14.07834E+03	-38.86498E+00	33.40798E-03
7	-14.66538E+04	34.30308E+03	-37.66987E+01	38.51612E-03

*** OVERLAY(3,3) //VORTS *** -

* VORT CALLED AT SPECIFIED OUTPUT TIME *

TABLE-1 SUMMARY INFORMATION

ITERATION NO. ITS	ITERATION NO. ITB	TIMEP (SEC)	ALTITUDE ALT (FT)	FREESTREAM MACH-NO. M=INF	STAGNATION PT. PRESSURE PT2 (ATM)	STAGNATION PT. ENTHALPY HO (BTU/LBM)
50	0	47.4524	1	5.000	3.2940	347.6

STAG. PT. RECESSION SPREC (INCH)	CURRENT NOSE RADIUS RN (INCH)	EFFECTIVE NOSE RADIUS R=EFF (INCH)	STAGNATION PT. HEAT TRANS. COEF. SPHTC (LBM/FT**2-SEC)	TRANSITION STREAM LENGTH S=TRAN (INCH)	SONIC PT. AXIAL LENGTH X=STAR (INCH)	SONIC PT. RADIAL LENGTH Y=STAR (INCH)
3.4017	.0093	.0090	2.4500	.0263	3.4041	.0062

TABLE-3 ENTROPY SWALLOWING INFORMATION

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, L = SHOCK POINT INDEX,
K = SHOCK POINT INDEX FOR STREAMLINE ENTRAINED IN BOUNDARY LAYER AT INTEGRATION POINT I

J	I	K	BODY GEOMETRY: STREAM LENGTH S (INCH)	AXIAL LENGTH X (INCH)	RADIAL LENGTH Y (INCH)	S OVER INPUT RADIUS S/R	BODY ANGLE (DEG)	L	SHOCK SHAPE: SHOCK AXIAL LENGTH X=SHOCK (INCH)	SHOCK RADIAL LENGTH Y=SHOCK (INCH)	SHOCK ANGLE BETA (DEG)	ENTROPY BEHIND SHOCK SRB	ENTROPY SWALLOWING: SWALLOWING PARAMETER YBAR (INCH)	EDGE ENTROPY ENTR
1	1	1	0.0000	3.4017	0.0000	0.0000	90.00	1	3.4002	0.0000	90.00	26.051	.0002	26.051
2	21	17	.1910	3.5588	.1061	.1273	32.74	21	3.5785	.1490	[illegible]	24.457	.0435	24.457
3	26	19	.3944	3.7323	.2122	.2629	31.44	2[illegible]	3.7805	.3075	37.24	24.354	.0971	24.457
4	29	21	.5498	3.8458	.3183	.3665	43.08	29	3.8551	.3734	51.15	25.189	.1526	24.457
5	31	22	.6962	3.9467	.4244	.4641	46.45	31	3.9374	.4800	52.84	25.242	.2097	24.435
6	33	24	.8363	4.0382	.5305	.5575	49.22	33	3.9981	.5651	54.84	25.306	.2660	24.398
7	35	26	.9815	4.1374	.6366	.6544	46.92	35	4.0862	.6845	53.19	25.253	.3192	24.362
8	37	29	1.1244	4.2330	.7427	.7496	47.98	37	4.1703	.7992	53.95	25.277	.3966	25.066
9	39	30	1.2610	4.3191	.8488	.8407	50.94	39	4.2453	.9087	56.15	25.349	.4533	25.257
10	41	31	1.3874	4.3379	.9549	.925	57.04	41	4.3039	1.0094	60.99	25.505	.5032	25.242
11	43	32	1.5060	4.4408	1.0610	1.004	63.52	43	4.3494	1.1365	66.25	25.667	.5550	25.285
12	45	33	1.6218	4.4571	1.1671	1.081	66.38	45	4.3908	1.2092	68.63	25.734	.6009	25.299
13	47	34	1.7378	4.5341	1.2732	1.1585	65.74	47	4.4343	1.3182	68.11	25.719	.6418	25.280
14	49	34	1.8545	4.5528	1.3793	1.2364	62.37	49	4.4844	1.4308	65.29	25.638	.6797	25.263
15	51	35	1.9780	4.6460	1.4854	1.3187	53.75	5[illegible]	4.5544	1.5525	58.40	25.422	.7090	25.255
16	61	35	2.7784	5.4165	1.7021	1.8523	13.36	61	8.3858	4.0549	18.60	22.740	.7077	25.260
17	64	36	4.0880	6.7080	1.9188	2.7253	9.25	64	13.7338	5.7435	15.18	22.309	.7524	25.265
18	67	37	5.4799	8.0529	2.1354	3.6533	8.85	67	17.6636	6.8042	14.87	22.272	.8008	25.274
19	71	37	6.9042	9.4907	2.3521	4.6029	8.65	71	20.5305	7.5621	14.70	22.255	.8487	25.301

AEROTHERM NOSE TIP ANALYSIS PROCEDURE (EROS)

TABLE-4 BOUNDARY CONDITIONS

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, NTB = TRANSITION FLAG

			----------BOUNDARY LAYER EDGE PROPERTIES----------									RECOVERY CONDITIONS		WALL CONDITIONS	
J	I	NTB	STREAM LENGTH	PRESSURE RATIO	EDGE MACH NO.	EDGE ENTHALPY	EDGE TEMP	EDGE DENSITY	EDGE VELOCITY	EDGE VISC.	EDGE REYNOLDS NO.	RECOVERY TEMP.	RECOVERY ENTHALPY	WALL TEMP	WALL ENTHALPY
			S (INCH)	PE/PT2	ME	HE (BTU/ LBM)	TE (R)	RHOE (LBM/ FT3)	VEL (FT/ SEC)	UE (LBM/ FT-SEC)	RE-EDGE (1/ FT)	TR (R)	HR (BTU/ LBM)	TW (R)	HW (BTU/ LBM)
1	1	-1	0,0000	1,0000	0,0000	347,6	1403,8	9,303E-02	0,0	2,421E-05	0,	1403,8	347,6	781,1	198,8
2	21	1	,1910	,3141	2,4042	161,1	668,9	6,134E-02	3047,3	1,471E-05	1,271E+07	1321,3	326,7	709,4	171,0
3	26	1	,3944	,2945	2,4418	158,4	657,8	5,847E-02	3069,2	1,453E-05	1,235E+07	1322,7	327,1	741,6	179,0
4	29	2	,5498	,4928	2,1099	178,9	742,5	8,492E-02	2897,9	1,585E-05	1,552E+07	1332,4	329,4	739,5	178,5
5	31	2	,6962	,5398	2,1241	183,6	757,9	9,303E-02	2865,8	1,609E-05	1,657E+07	1334,0	329,9	745,2	179,9
6	33	2	,8363	,5364	2,1012	187,0	765,6	1,000E-01	2849,4	1,620E-05	1,759E+07	1334,9	330,3	749,0	180,8
7	35	2	,9215	,5479	2,1537	184,2	747,9	9,567E-02	2886,6	1,594E-05	1,733E+07	1332,9	330,0	748,5	180,7
8	37	2	1,1248	,5557	1,6880	185,5	914,5	8,079E-02	2501,8	1,832E-05	1,103E+07	1350,9	330,1	749,9	181,0
9	39	2	1,2610	,6152	1,4771	189,4	996,1	8,067E-02	2284,6	1,940E-05	9,497E+06	1359,7	330,5	753,9	182,0
10	41	2	1,3874	,7131	1,3691	199,5	1039,6	9,968E-02	2162,3	1,995E-05	9,720E+06	1364,3	331,6	760,1	183,6
11	43	2	1,5060	,8072	1,2337	208,1	1092,0	9,656E-02	1997,9	2,062E-05	9,357E+06	1370,1	332,6	766,0	185,0
12	45	2	1,6218	,8447	1,1857	211,2	1110,8	9,929E-02	1936,7	2,085E-05	9,223E+06	1372,1	332,9	767,9	185,5
13	47	2	1,7378	,8364	1,1089	210,5	1101,7	9,916E-02	1965,5	2,074E-05	9,403E+06	1371,2	332,8	768,4	185,6
14	49	2	1,8545	,7916	1,2678	206,7	1078,5	9,586E-02	2040,5	2,045E-05	9,563E+06	1368,7	332,4	765,8	185,0
15	51	2	1,9780	,6612	1,4198	194,3	1019,5	8,478E-02	2220,7	1,969E-05	9,360E+06	1362,2	331,1	757,9	183,0
16	61	2	2,7784	,1098	2,5543	119,2	625,8	2,283E-02	3131,5	1,400E-05	5,106E+06	1319,8	323,0	682,6	164,4
17	64	2	4,0880	,0915	2,7437	108,6	575,7	1,849E-02	3226,6	1,316E-05	4,534E+06	1314,4	321,8	671,7	161,8
18	67	2	5,4799	,0722	2,8218	104,3	556,5	1,695E-02	3262,2	1,282E-05	4,313E+06	1312,3	321,3	667,5	160,7
19	71	2	6,9042	,0659	2,8689	101,0	545,2	1,578E-02	3283,0	1,262E-05	4,105E+06	1311,1	321,0	664,4	166,0

AEROTHERM NOSE TIP ANALYSIS PROCEDURE (ENOS)

TABLE-5 HEAT TRANSFER AND BOUNDARY LAYER QUANTITIES

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, NTB = TRANSITION FLAG

J	I	NTB	STREAM LENGTH S (INCH)	NON-BLOWN HEAT FLUX QDOT (BTU/ FT2-SEC)	HEAT TRANS. COEF, BASED ON TR HTC (BTU/ FT2-SEC-R)	HEAT TRANS. COEF, BASED ON HR CHO (LBM/ FT2-SEC)	LAMINAR HEATING PARAMETER FL	TURBULENT HEATING PARAMETER FT	WEIGHTING PARAMETER FFT	NET HEATING PARAMETER FCHT	LAMINAR MOMENTUM THICKNESS THETA-LAM (MIL)	DISPLACE-MENT THICKNESS DELSTR (MIL)	LAMINAR, MOMENTUM REYN. NO. RETHL
1	1	-1	0,0000	5,0127E+02	5,0502E-01	3,1555	1,2880	1,2880	0,0000	1,2880	,034	,032	0,00
2	21	1	,1910	1,2505E+02	2,0436E-01	,8034	,1298	,3574	,9150	,3279	,149	,354	157,99
3	26	1	,3944	9,9163E+01	1,7064E-01	,6696	,0803	,2781	,9861	,2733	,224	,573	230,38
4	29	2	,5498	1,5047E+02	2,5381E-01	,9959	,1001	,4110	,9930	,r064	,196	,429	253,44
5	31	2	,6962	1,5457E+02	2,6250E-01	1,0302	,0911	,4228	,9964	,4205	,219	,472	299,67
6	33	2	,8363	1,5922E+02	2,7004E-01	1,0595	,0854	,4336	,9977	,4320	,238	,508	337,79
7	35	2	,9815	1,4274E+02	2,4423E-01	,9562	,0738	,3913	,9985	,3903	,278	,611	381,80
8	37	2	1,1244	1,1231E+02	1,9687E-01	,7534	,0685	,3079	,9990	,3075	,294	,497	411,13
9	39	2	1,2610	1,0500E+02	1,7332E-01	,7071	,0685	,2849	,9992	,2846	,298	,451	432,96
10	41	2	1,3874	1,1230E+02	1,9556E-01	,7584	,0719	,3399	,9992	,3096	,275	,425	441,55
11	43	2	1,5060	1,1323E+02	1,8743E-01	,7675	,0742	,3135	,9993	,3133	,295	,379	453,03
12	45	2	1,6218	1,1233E+02	1,8589E-01	,7620	,0724	,3113	,9994	,31'	,306	,404	474,35
13	47	2	1,7378	1,1162E+02	1,8520E-01	,7594	,0691	,3098	,9994	,3095	,324	,434	500,75
14	49	2	1,8545	1,0907E+02	1,8092E-01	,7395	,0656	,3022	,9995	,3020	,348	,478	531,43
15	51	2	1,9780	9,9490E+01	1,6464E-01	,6720	,0582	,2745	,9996	,2743	,395	,581	580,81
16	61	2	2,7784	1,9746E+01	3,0990E-02	,1246	,0114	,0509	,9997	,0505	1,534	3,770	1059,65
17	64	2	4,0880	1,3555E+01	2,1095E-02	,0847	,0077	,0346	,9997	,0346	1,885	5,040	1170,22
18	67	2	5,4799	1,1903E+01	1,8307E-02	,0735	,0066	,0300	,9997	,0300	2,050	5,674	1224,25
19	71	2	6,9042	1,0737E+01	1,6696E-02	,0671	,0060	,0274	,9997	,0274	2,188	6,171	1271,55

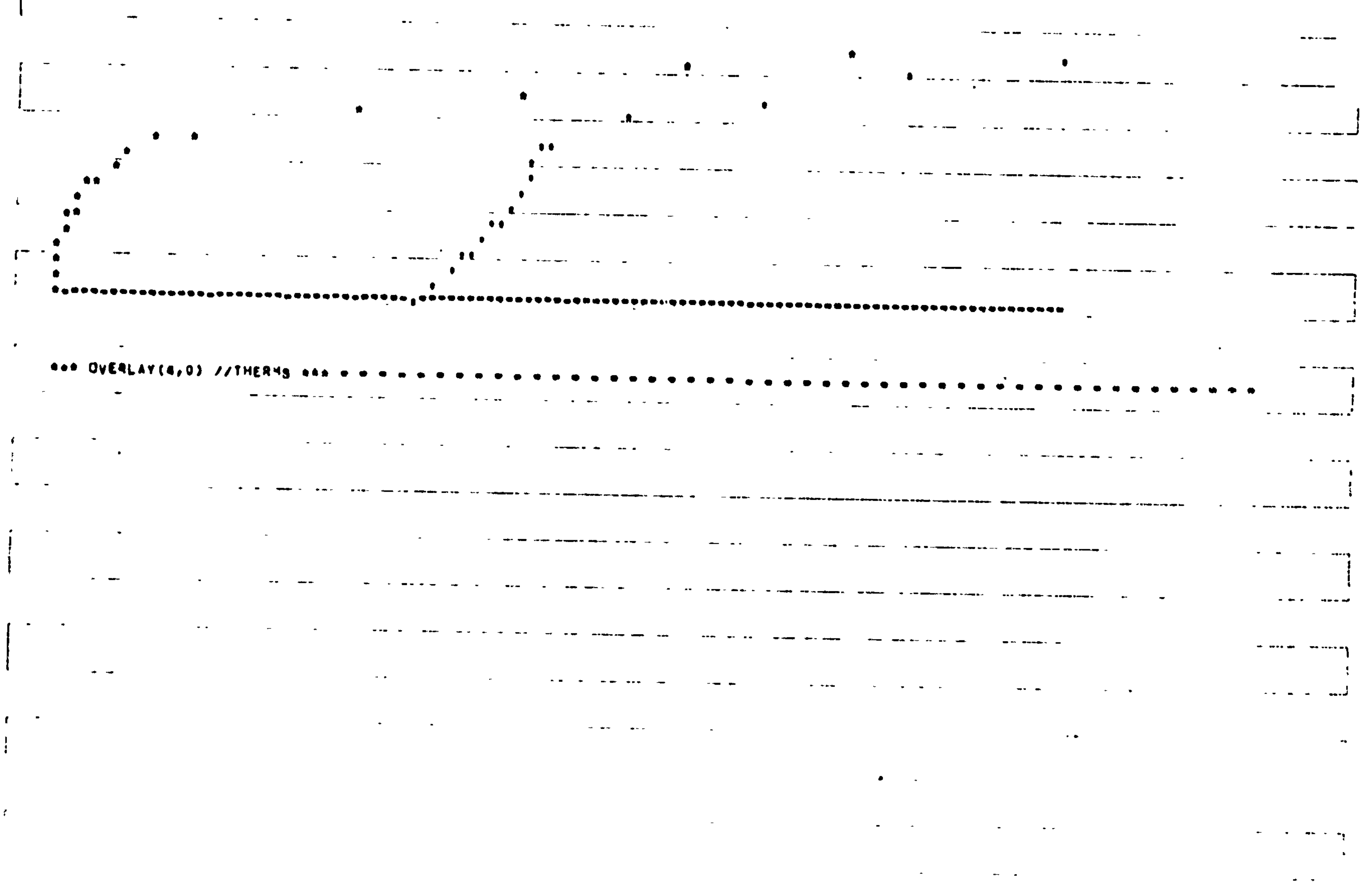
TABLE-6 ROUGHNESS HEATING QUANTITIES TIME= 47.45 SEC RUN 207 PAGE266

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, NTB = TRANSITION FLAG

J	I	NTB	STREAM LENGTH S (INCH)	LAMINAR ROUGH STANT NO. STANTL	COMPOSITE ROUGH STANT NO. STANTT	COMPOSITE SMOOTH STANT NO. STANTS	TRANSITION ROUGH STANT NO. STANTN	ROUGHNESS HEIGHT K (MIL)	DELSTR TRANSITION PARAMETER	THEATA TRANSITION PARAMETER	TURBULENT ROUGHNESS HEATING PARAMETER	NET ROUGHNESS HEATING FACTOR	TURBULENT MOMENTUM REYN. NO. RETHT
1	1	-1	0.0000	0.	0.	0.	0.	.96	0.000	0.	0.	1.288	0.
2	21	1	.1910	1.7015E-03	4.6841E-03	2.7678E-03	4.2977E-03	2.20	8280.445	9.9741E+02	1.1357E+02	1.633	5.8246E+02
3	26	1	.3944	1.0962E-03	3.7966E-03	2.3065E-03	3.7316E-03	2.20	8723.760	1.0490E+03	9.3065E+01	1.637	1.1716E+03
4	29	2	.5498	9.9607E-04	4.0913E-03	2.3415E-03	4.[illegible]9E-03	2.20	13490.238	1.3814E+03	1.3844E+02	1.742	1.6311E+03
5	31	2	.6962	8.3780E-04	3.8857E-03	2.2074E-03	3.8643E-03	2.20	15088.626	1.5223E+03	1.4592E+02	1.758	2.1737E+03
6	33	2	.8363	7.3380E-04	3.7270E-03	2.1039E-03	3.7136E-03	2.20	16619.831	1.6296E+03	1.5223E+02	1.770	2.7055E+03
7	35	2	.9815	6.5507E-04	3.4711E-03	1.9818E-03	3.4624E-03	2.20	16234.056	1.6252E+03	1.4129E+02	1.750	3.2448E+03
8	37	2	1.1244	8.2969E-04	3.7338E-03	2.1928E-03	3.7272E-03	2.20	11586.644	1.9315E+03	1.2258E+02	1.702	3.6623E+03
9	39	2	1.2610	9.1075E-04	3.8425E-03	2.2703E-03	3.8367E-03	2.20	10707.475	2.1301E+03	1.1917E+02	1.692	3.9223E+03
10	41	2	1.3874	9.0847E-04	3.9169E-03	2.2884E-03	3.9113E-03	2.20	11536.341	2.2404E+03	1.2791E+02	1.711	4.1578E+03
11	43	2	1.5060	9.4210E-04	3.9835E-03	2.3194E-03	3.9784E-03	2.20	11655.189	2.3699E+03	1.3099E+02	1.717	4.3840E+03
12	45	2	1.6218	9.2187E-04	3.9677E-03	2.3091E-03	3.9630E-03	2.20	11721.347	2.4443E+03	1.3131E+02	1.718	4.6045E+03
13	47	2	1.7378	8.6876E-04	3.8934E-03	2.2655E-03	3.8892E-03	2.20	11946.555	2.4655E+03	1.3106E+02	1.718	4.8289E+03
14	49	2	1.8545	8.2194E-04	3.7860E-03	2.2085E-03	3.7823E-03	2.20	12018.739	2.4578E+03	1.2861E+02	1.714	5.0572E+03
15	51	2	1.9780	7.5755E-04	3.5724E-03	2.1107E-03	3.5693E-03	2.20	11502.110	2.3781E+03	1.1824E+02	1.692	5.2960E+03
16	61	2	2.7784	3.9055E-04	1.7431E-03	1.4858E-03	1.7422E-03	1.25	3689.643	8.6518E+02	1.8346E+01	1.173	6.4581E+03
17	64	2	4.0880	3.1439E-04	1.4208E-03	1.3819E-03	1.4201E-03	.96	3382.970	6.5502E+02	1.1035E+01	1.028	6.8775E+03
18	67	2	5.4799	2.9087E-04	1.3299E-03	1.3299E-03	1.3292E-03	.96	3410.419	6.3362E+02	9.9308E+00	1.000	7.1660E+03
19	71	2	6.9082	2.8108E-04	1.2949E-03	1.2949E-03	1.2943E-03	.96	3808.914	6.2205E+02	9.1386E+00	1.000	7.4058E+03
			.96000000		3.29395666	1403.78169790		4514934.488183147					

AEROTHERM NOSE TIP ANALYSIS PROCEDURE (ERDS)

*** CURRENT SHAPE ON NOSE *** TIME=, 47.45 SEC RUN 207 PAGE267



AEROTHERM NOSE TIP ANALYSIS PROCEDURE (EROS)

BODY POINT LOCATIONS AND SURFACE ENERGY BALANCE RESULTS AT
TIME = 47,9524 SEC

* DENOTES ANGLE LIMIT

POINT NUMBER	Z (INCHES)	Z-DOT USED	WALL TEMPERATURE (DEG R)	S-DOT TOTAL (IN/SEC)	S-DOT EROSION (IN/SEC)	PARTICLE ROUGHNESS (MILS)	B-PRIME THERMO-CHEM	CHH	CH (LBM/FT**2-SEC)	CHZ
1	3,52362	,24390	781,18	24,3596E-02	0,	0,	51,2063E-02	55,9656E+01	25,4821E-01	3,15554
2	3,62348	,12936	724,68	69,9538E-03	0,	0,	51,8410E-02	14,3450E+01	72,1924E-02	,80337
3	3,78052	,09639	722,12	59,3990E-03	0,	0,	52,3661E-02	12,0801E+01	60,6851E-02	,66464
4	3,90608	,12055	744,39	84,9621E-03	0,	0,	50,0707E-02	18,2841E+01	90,7811E-02	,99692
5	4,00533	,11731	749,47	86,9897E-03	0,	0,	49,5482E-02	18,9649E+01	93,9277E-02	1,03023
6	4,09785	,11928	753,09	88,7717E-03	0,	0,	49,1623E-02	19,5412E+01	96,6043E-02	1,05849
7	4,19215	,10948	750,04	80,6646E-03	0,	0,	49,4749E-02	17,6178E+01	87,2272E-02	,95617
8	4,27467	,08334	751,46	63,3676E-03	0,	0,	49,3103E-02	13,8961E+01	68,7517E-02	,75338
9	4,35554	,07289	755,22	59,0303E-03	0,	0,	48,9264E-02	13,0777E+01	64,5703E-02	,70708
10	4,42395	,07211	761,94	62,6929E-03	0,	0,	48,3808E-02	14,1171E+01	69,3265E-02	,75844
11	4,47546	,06941	767,57	62,8878E-03	0,	0,	47,9212E-02	14,3616E+01	70,2089E-02	,76748
12	4,52115	,06800	769,61	62,2434E-03	0,	0,	47,7541E-02	14,2875E+01	69,7327E-02	,76205
13	4,56810	,06799	769,18	61,9850E-03	0,	0,	47,7889E-02	14,2129E+01	69,3927E-02	,75837
14	4,61703	,06851	766,68	60,7010E-03	0,	0,	47,9912E-02	13,8321E+01	67,6687E-02	,73978
15	4,68061	,06923	758,50	55,8369E-03	0,	0,	48,6533E-02	12,4684E+01	61,3992E-02	,67201
16	5,44218	,05140	683,35	11,8795E-03	0,	0,	56,6040E-02	21,8894E+00	11,2280E-02	,12456
17	6,73359	,05113	672,15	82,1792E-04	0,	0,	57,6833E-02	14,7725E+00	76,2195E-03	,08471
18	8,10624	,04662	667,91	71,7642E-04	0,	0,	58,1060E-02	12,7755E+00	66,0754E-03	,07349
19	9,51258	,04378	664,70	65,8103E-04	0,	0,	58,4332E-02	11,6284E+00	60,2543E-03	,06705

TOTAL STAGNATION POINT RECESSION DUE TO EROSION ONLY = 0,0000 INCHES

*** OVERLAY(3,0) //ENVIR; *** *

*** OVERLAY(3,1) //VORTI *** *

SHOULDER POINT = 17 SONIC POINT = 2

*** OVERLAY(3,2) //VORTIS *** *

NEW CURVE FIT DONE TO BODY POINTS
3CURVES FIT TO, 10 POINTS

CURVE	A	B	C	AUC(I>1)
1	-99,03395E+04	57,80501E+04	10,85458E-16	53,85361E-05
2	-52,14159E+05	58,25994E+04	-12,24997E-01	13,31828E-04
3	92,30216E+05	34,41246E+04	24,39594E+00	23,30954E-04

*** OVERLAY(3,3) //VORTS *** *

Sample Problem No. 2

Sample Problem No. 2 is a steady state weather flight prediction of a 9° ATJ-S graphite sphere cone nosetip with a 0.65-inch nose radius.

This problem demonstrates the use of the flight environment option. In addition, the weather option is utilized. Also, the sphere-cone input option is repeated.

```
 0  0
C    INPUT DATA
       WEATHER
     STEADY STATE
        SPM 7                                                            S.M 7
01
     3.95        17.05        .2          .0          200.
 -5  1  2  2  1  2  4  2
      .5          8.
02
      3.95         3005.        3226.
      4.45         3884.        3819.
      4.95         4861.        4063.
      5.25         5403.        4050.
      5.35         5709.        4410.
      5.55         6170.        4900.
      5.75         6632.        5461.
      6.52         9164.        7884.
      6.65         9665.        8270.
      6.75        10063.        8520.
      6.8         10256.        8575.
      6.85        10469.        8570.
      6.95        10881.        8545.
      7.05        11294.        8480.
      7.25        12119.        8322.
      9.05        18601.        6563.
     11.05        24280.        5209.
     14.05        30636.        3925.
     17.05        35381.        3119.
03
   20   11 .050166   .41666        9.         540.       1
05
  -16  5640.          0.
  0.0      .122      1020.     1.
  750.     .117      1010.     1.
  1000.    .214      1005.     1.
  1250.    .239      1280.     1.
  1500.    .400      1355.     1.
  2000.    .497      1300.     1.
  2250.    .260      1255.     1.
  2500.    .416      1115.     1.
  3250.    .138      880.      1.
  4000.    .116      800.      1.
  4250.    .166      665.      1.
  4500.    .153      530.      1.
  5250.    .013      285.      1.
  5500.    .003      120.      1.
  5750.    .033      120.      1.
  5840.    0.0       0.        1.
06
 1   117. 536.      0.0        .233       -.15
 1
        8.E-6    1.6          0.0             .62
 2 .0004       -.020         .93
  460.      .031        .0297    1.
```

```
   960.      .034      .0233    1.
  1460.      .035      .0204    1.
  1960.      .037      .0190    1.
  2460.      .038      .0178    1.
  2960.      .040      .0169    1.
   3460.     .041      .0162    1.
  5000.      .050      .0149    1.
*19000.      .071      .0103    1.
09
    1
    1 1.
   .0100   .00000 4.000003325.6166 .000 5595.743 5595.743 1  C      *  .000
   .0100   .00000 2.000003291.4387 .000 4584.223 4584.223 1  C      *   000
   .0100   .00000 1.800003280.6345 .000 4401.955 4401.955 1  C      *  .000
   .0100   .00000 1.600003276.4585 .000 4191.066 4191.066 1  C      *  .000
   .0100   .00000 1.400003266.4207 .000 3944.237 3944.237 1  C      *  .000
   .0100   .00000 1.200003253.7092 .000 3651.409 3651.409 1  C      *  .000
   .0100   .00000 1.000003237.1379 .000 3298.330 3298.330 1  C      *  .000
   .0100   .00000  .800003214.1368 .000 2864.031 2864.031 1  C      *  .000
   .0100   .00000  .600003179.3200 .000 2316.016 2316.016 1  C      *  .000
   .0100   .00000  .500003153.4915 .000 1983.635 1983.635 1  C      *  .000
   .0100   .00000  .400003116.3879 .000 1599.073 1599.073 1  C      *  .000
   .0100   .00000  .350003090.1551 .000 1382.302 1382.302 1  C      *  .000
   .0100   .00000  .300003054.1960 .000 1144.975 1144.975 1  C      *  .000
   .0100   .00000  .250002998.2509 .000  880.830  880.830 1  C      *  .000
   .0100   .00000  .220002961.0398 .000  703.014  703.014 1  C      *  .000
   .0100   .00000  .200002873.5727 .000  568.912  568.912 1  C      *  .000
   .0100   .00000  .190002812.8187 .000  490.765  490.765 1  C      *  .000
   .0100   .00000  .180002665.6900 .000  382.537  382.537 1  C      *  .000
   .0100   .00000  .17500 935.9083 .000 -166.633 -166.633 1  C      *  .000
   .0100   .00000  .17000 871.8156 .000 -200.897 -200.897 1  C      *  .000
  1.0000   .00000 4.000003986.7787 .000 5784.608 5784.608 1  C      *  .000
  1.0000   .00000 2.000003930.7377 .000 4772.770 4772.770 1  C      *  .000
  1.0000   .00000 1.800003919.7692 .000 4589.993 4589.993 1  C      *  .000
  1.0000   .00000 1.600003906.6368 .000 4378.359 4378.359 1  C      *  .000
  1.0000   .00000 1.400003890.5510 .000 4130.456 4130.456 1  C      *  .000
  1.0000   .00000 1.200003870.4112 .000 3836.082 3836.082 1  C      *  .000
  1.0000   .00000 1.000003844.1268 .000 3480.735 3480.735 1  C      *  .000
  1.0000   .00000  .800003807.9968 .000 3043.019 3043.019 1  C      *  .000
  1.0000   .00000  .600003753.8412 .000 2489.554 2489.554 1  C      *  .000
  1.0000   .00000  .500003713.9969 .000 2153.084 2153.084 1  C      *  .000
  1.0000   .00000  .400003657.2362 .000 1762.765 1762.765 1  C      *  .000
  1.0000   .00000  .350003617.3726 .000 1541.949 1541.949 1  C      *  .000
  1.0000   .00000  .300003563.1188 .000 1299.272 1299.272 1  C      *  .000
  1.0000   .00000  .250003479.3765 .000 1027.102 1027.102 1  C      *  .000
  1.0000   .00000  .220003394.5348 .000  841.391  841.391 1  C      *  .000
  1.0000   .00000  .200003295.4901 .000  698.292  698.292 1  C      *  .000
  1.0000   .00000  .190003207.2959 .000  612.293  612.293 1  C      *  .000
  1.0000   .00000  .180002998.6384 .000  486.075  486.075 1  C      *  .000
  1.0000   .00000  .175001185.8390 .000  -95.869  -95.869 1  C      *  .000
  1.0000   .00000  .170001083.4739 .000 -141.269 -141.269 1  C      *  .000
 10.0000   .00000 4.000004427.1046 .000 5921.222 5921.222 1  C      *  .000
 10.0000   .00000 2.000004356.7841 .000 4899.925 4899.925 1  C      *  .000
 10.0000   .00000 1.800004335.9129 .000 4715.167 4715.167 1  C      *  .000
 10.0000   .00000 1.600004318.1919 .000 4501.168 4501.168 1  C      *  .000
 10.0000   .00000 1.400004296.4675 .000 4250.411 4250.411 1  C      *  .000
 10.0000   .00000 1.200004269.3253 .000 3952.544 3952.544 1  C      *  .000
```

```
 10.0000  .00000 1.000004234.0784 .000 3592.893 3592.893 1  C    *   .000
 10.0000  .00000  .800004185.9462 .000 3149.767 3149.767 1  C    *   .000
 10.0000  .00000  .600004114.3455 .000 2589.345 2589.345 1  C    *   .000
 10.0000  .00000  .500004062.0876 .000 2248.566 2248.566 1  C    *   .000
 10.0000  .00000  .400003780.2143 .000 1853.031 1853.031 1  C    *   .000
 10.0000  .00000  .350003736.7399 .000 1629.144 1629.144 1  C    *   .000
 10.0000  .00000  .300003867.0729 .000 1382.716 1382.716 1  C    *   .000
 10.0000  .00000  .250003760.5196 .000 1105.443 1105.443 1  C    *   .000
 10.0000  .00000  .220003653.6239 .000  914.960  914.960 1  C    *   .000
 10.0000  .00000  .200003530.0830 .000  766.422  766.422 1  C    *   .000
 10.0000  .00000  .190003421.1620 .000  675.551  675.551 1  C    *   .000
 10.0000  .00000  .180003167.3427 .000  537.650  537.650 1  C    *   .000
 10.0000  .00000  .175001371.4072 .000  -41.901  -41.901 1  C    *   .000
 10.0000  .00000  .170001235.0237 .000  -97.718  -97.718 1  C    *   .000
100.0000  .00000 4.000004977.5407 .000 6087.707 6087.707 1  C    *   .000
100.0000  .00000 2.000004867.2645 .000 5040.494 5040.494 1  C    *   .000
100.0000  .00000 1.800004845.6840 .000 4850.640 4850.640 1  C    *   .000
100.0000  .00000 1.600004819.9086 .000 4630.828 4630.828 1  C    *   .000
100.0000  .00000 1.400004788.4765 .000 4373.251 4373.251 1  C    *   .000
100.0000  .00000 1.200004749.2472 .000 4067.475 4067.475 1  C    *   .000
100.0000  .00000 1.000004699.5228 .000 3698.719 3698.719 1  C    *   .000
100.0000  .00000  .800004629.7045 .000 3245.377 3245.377 1  C    *   .000
100.0000  .00000  .600004528.7063 .000 2674.121 2674.121 1  C    *   .000
100.0000  .00000  .500004456.0787 .000 2323.097 2323.097 1  C    *   .000
100.0000  .00000  .400004354.9696 .000 1927.815 1927.815 1  C    *   .000
100.0000  .00000  .350004285.5280 .000 1701.816 1701.816 1  C    *   .000
100.0000  .00000  .300004192.7731 .000 1453.371 1453.371 1  C    *   .000
100.0000  .00000  .250004053.3203 .000 1173.626 1173.626 1  C    *   .000
100.0000  .00000  .220003915.9349 .000  980.357  980.357 1  C    *   .000
100.0000  .00000  .200003759.7763 .000  827.635  827.635 1  C    *   .000
100.0000  .00000  .190003624.1610 .000  732.212  732.212 1  C    *   .000
100.0000  .00000  .180003314.3014 .000  581.655  581.655 1  C    *   .000
100.0000  .00000  .175001630.3400 .000   34.688   34.688 1  C    *   .000
100.0000  .00000  .170001439.5134 .000  -38.261  -38.261 1  C    *   .000
500.0000  .00000 4.000005452.7357 .000 6225.165 6225.165 1  C    *   .000
500.0000  .00000 2.000005304.1459 .000 5138.615 5138.615 1  C    *   .000
500.0000  .00000 1.800005274.5570 .000 4941.085 4941.085 1  C    *   .000
500.0000  .00000 1.600005234.0687 .000 4712.312 4712.312 1  C    *   .000
500.0000  .00000 1.400005195.6724 .000 4444.533 4444.533 1  C    *   .000
500.0000  .00000 1.200005141.4257 .000 4127.279 4127.279 1  C    *   .000
500.0000  .00000 1.000005071.4277 .000 3746.099 3746.099 1  C    *   .000
500.0000  .00000  .800004977.1852 .000 3280.424 3280.424 1  C    *   .000
500.0000  .00000  .600004841.2944 .000 2699.451 2699.451 1  C    *   .000
500.0000  .00000  .500004745.6046 .000 2351.065 2351.065 1  C    *   .000
500.0000  .00000  .400004615.5325 .000 1951.367 1951.367 1  C    *   .000
500.0000  .00000  .350004527.4734 .000 1727.121 1727.121 1  C    *   .000
500.0000  .00000  .300004413.0676 .000 1481.590 1481.590 1  C    *   .000
500.0000  .00000  .250004223.9567 .000 1205.311 1205.311 1  C    *   .000
500.0000  .00000  .220004080.7421 .000 1013.670 1013.670 1  C    *   .000
500.0000  .00000  .200003898.3866 .000  860.399  860.399 1  C    *   .000
500.0000  .00000  .190003782.1595 .000  762.851  762.851 1  C    *   .000
500.0000  .00000  .180003391.9579 .000  604.424  604.424 1  C    *   .000
500.0000  .00000  .175001983.5403 .000  110.962  110.962 1  C    *   .000
500.0000  .00000  .170001628.6398 .000   18.164   18.164 1  C    *   .000

-1
C    END OF INPUT DATA
```

WEATHER
STEADY STATE
SAM 7

SAM 7

GENERAL PROGRAM CONSTANTS

(TRANSITION CRITERIA CONTROL)	TC = -5
(ENVIRONMENT CRITERIA CONTROL)	ENV = 1
(CURVE FIT CONTROL)	CF = 2
(MATERIAL CONSTANT)	MC = 2
(NO. OF TIME INTERVAL CHANGES)	NTIC = 1
(STEADY STATE FLAG)	ISS = 2
(OUTPUT PRINT CONTROL)	IPRNT = 4
(INTERMEDIATE TIME PRINT CONTROL)	LPRNT = 2

TIME INCREMENT INFORMATION

INITIAL TIME (SEC) 3.9500 FINAL TIME (SEC) 17.0500

OUTPUT INTERVAL = .2000 SEC FROM INITIAL TIME UNTIL 8.0000 SEC
OUTPUT INTERVAL = .5000 SEC FROM 8.0000 SEC UNTIL FINAL TIME

TIME STEP STABILITY CRITERIA IN EFFECT
MINIMUM TIME STEP =1.0000E-06SECONDS
CTP = 1.300 STRD = 75.000

FLIGHT ENVIRONMENT

TIME (SEC)	ALTITUDE (FT)	VELOCITY (FPS)
3.950	3005.0	3226.0
4.450	3884.0	3819.0
4.950	4861.0	4063.0
5.210	5403.0	4054.0
5.350	5709.0	4410.0
5.550	6174.0	4900.0
5.750	6682.0	5461.0
6.520	9164.0	7884.0
6.650	9665.0	8270.0
6.750	10063.0	8520.0
6.800	10266.0	8575.0
6.850	10469.0	8570.0
6.950	10881.0	8545.0
7.050	11294.0	8480.0
7.250	12119.0	8322.0
9.050	16661.0	6583.0
11.050	24280.0	5209.0
14.050	30636.0	3925.0
17.050	35381.0	3119.0

BUILT-IN ATMOSPHERIC TABLE, 1962 U.S. STANDARD.

I	ALTITUDE(FT)	DENSITY(LBM/FT3)	PRESSURE(ATM)
1	0.	7.647400E-02	1.000000E+00
2	3.000000E+03	6.998400E-02	8.962600E-01
3	6.000000E+03	6.392500E-02	8.014300E-01
4	1.000000E+04	5.648300E-02	6.878300E-01
5	2.000000E+04	4.077300E-02	4.599100E-01
6	3.000000E+04	2.865700E-02	2.975400E-01
7	4.000000E+04	1.889500E-02	1.857700E-01
8	5.000000E+04	1.170900E-02	1.151200E-01
9	6.000000E+04	7.258900E-03	7.136600E-02
10	7.000000E+04	4.478700E-03	4.429000E-02
11	8.000000E+04	2.757600E-03	2.764900E-02
12	9.000000E+04	1.710000E-03	1.737900E-02
13	1.000000E+05	1.067600E-03	1.099700E-02
14	1.100000E+05	6.647000E-04	7.011200E-03
15	1.200000E+05	4.150600E-04	4.537100E-03
16	1.300000E+05	2.635300E-04	2.981500E-03
17	1.400000E+05	1.699400E-04	1.987600E-03
18	1.500000E+05	1.111900E-04	1.342900E-03
19	1.600000E+05	7.471300E-05	9.176400E-04
20	1.700000E+05	5.115900E-05	6.283400E-04
21	1.800000E+05	3.557800E-05	4.292800E-04
22	1.900000E+05	2.466300E-05	2.908500E-04
23	2.000000E+05	1.695700E-05	1.953700E-04
24	2.100000E+05	1.174800E-05	1.296400E-04
25	2.200000E+05	8.035600E-06	8.431900E-05
26	2.300000E+05	5.388800E-06	5.362700E-05
27	2.400000E+05	3.535300E-06	3.326900E-05
28	2.500000E+05	2.263000E-06	2.007400E-05
29	2.600000E+05	1.409000E-06	1.174700E-05
30	2.700000E+05	8.172000E-07	6.694400E-06
31	2.800000E+05	4.661000E-07	3.821100E-06
32	3.000000E+05	1.488000E-07	1.248900E-06
33	3.200000E+05	4.774000E-08	4.403400E-07
34	3.400000E+05	1.654000E-08	1.717000E-07
35	3.600000E+05	6.385000E-09	7.513300E-08
36	3.800000E+05	2.579000E-09	3.732200E-08
37	4.000000E+05	1.164000E-09	2.107100E-08
38	4.200000E+05	5.751000E-10	1.359700E-08
39	4.400000E+05	3.301000E-10	9.631500E-09
40	4.600000E+05	2.088000E-10	7.248500E-09

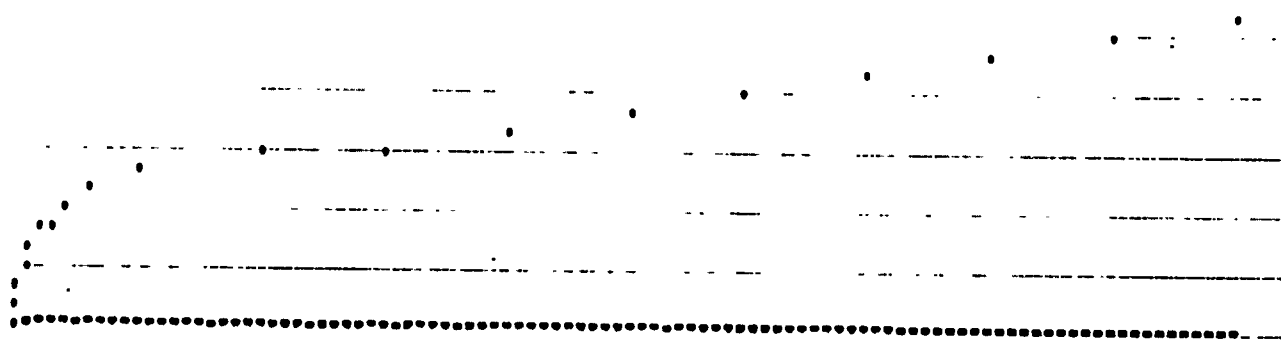
INITIAL GEOMETRY---

SPHERE CONE OPTION - GENERATED SHAPE

INITIAL NOSE RADIUS = ,6500 INCHES
CONE ANGLE = 9,0000 DEGREES
MAXIMUM =Z= = 4,9999 INCHES

I	ZOUT	ROUT	SLOP
1	0,00000	0,00000	90,00000
			87,15880
2	,00318	,06420	84,31761
			81,46230
3	,01281	,12840	78,60700
			75,68555
4	,02919	,19260	72,76410
			69,74672
5	,05288	,25680	66,72933
			63,56788
6	,08479	,32099	60,40644
			57,03189
7	,12643	,38519	53,65735
			49,95888
8	,18038	,44939	46,26041
			42,03041
9	,25160	,51359	37,80041
			32,53131
10	,35225	,57779	27,26222
			21,36628
11	,54831	,64199	15,47035
			12,23518
12	1,04293	,72033	9,00000
			9,00000
13	1,53756	,79867	9,00000
			9,00000
14	2,03218	,87701	9,00000
			9,00000
15	2,52680	,95535	9,00000
			9,00000
16	3,02143	1,03369	9,00000
			9,00000
17	3,51605	1,11203	9,00000
			9,00000
18	4,01067	1,19037	9,00000
			9,00000
19	4,50530	1,26871	9,00000
			9,00000
20	4,99992	1,34706	9,00000

---INITIAL SHAPE PLOT---



FEVAP=-C NRUFF=-0 NOSLJ=-0 NOHEAL=-0 MAXER=0 MAXMO=0 IGEOM= 1

CLOUD PROPERTIES

ALTITUDE FT	DENSITY GM/M**3	DROP SIZE MICRONS	
0	.122	1020	1.000
2461	.117	1010	1.000
3281	.214	1005	1.000
4101	.239	1280	1.000
4921	.400	1355	1.000
6562	.497	1300	1.000
7382	.260	1255	1.000
8202	.416	1115	1.000
10663	.138	880	1.000
13123	.116	800	1.000
13944	.166	685	1.000
14764	.153	530	1.000
17224	.013	245	1.000
18045	.003	120	1.000
18865	.033	120	1.000
19160	0.000	0	1.000

MATERIAL PROPERTIES

******* M A T E R I A L   N U M B E R   1. *******

SURFACE ROUGHNESS

ROUGHNESS HEIGHT FOR LAMINAR HEATING AND TRANSITION   K-LAM = .00040 (INCH)

TURBULENT SCALLOP ROUGHNESS MODEL IN EFFECT   K-TURB = K1/P**0.77
ROUGHNESS SCALLOP HEIGHT AT P = 1.0 PSIA   K1 = .93000 (INCH)
MAXIMUM ROUGHNESS SCALLOP HEIGHT   K-MAX = .02000 (INCH)
MINIMUM ROUGHNESS SCALLOP HEIGHT   K-MIN = .00040 (INCH)

FLAG FOR TYPE OF ROUGH TURBULENT HEATING   JROUGH = 2

THERMAL PROPERTIES

RHO = 117.00
TFO = 536.00
HFO = 0.00
TBRPL = .23
TBNPT = -.15

TEMPERATURE (DEG R)	SPECIFIC HEAT (BTU/LB-DEG)	CONDUCTIVITY (BTU/FT-SEC-DEG)	SENSIBLE ENTHALPY (BTU/LB)	EMISSIVITY
460.00	.0310	.0297000	-2.47	1.0000
960.00	.0340	.0233000	13.78	1.0000
1460.00	.0350	.0204000	31.03	1.0000
1960.00	.0370	.0190000	49.03	1.0000
2460.00	.0380	.0178000	67.78	1.0000
2960.00	.0400	.0169000	87.28	1.0000
3460.00	.0410	.0162000	107.53	1.0000
5000.00	.0500	.0149000	177.60	1.0000
9000.00	.0710	.0183000	419.60	1.0000

---SURFACE EQUILIBRIUM DATA---

MAT = 1
NBPF = 1
CMM = 1.00000

M-DOT-GAS/CM = 0.0000   PRESSURE = .0100 ATM

TEMP	BPRIM	HCH	TSEN	TCHEM	SPECIE
1569.2681	.1700	34.9637	-361.6146	429.0329	C
1684.7789	.1750	39.1220	-300.2994	359.6982	C
4798.6020	.1800	168.4364	688.5666	-782.1900	C
5063.0737	.1900	181.4160	883.3770	-1016.7496	C
5172.4309	.2000	188.0321	1024.0416	-1191.2435	C
5293.9716	.2200	195.3772	1265.0252	-1500.8353	C
5396.8516	.2500	201.6095	1585.4940	-1931.4651	C
5497.5528	.3000	207.7019	2060.9550	-2616.9309	C
5562.2792	.3500	211.6179	2488.1436	-3284.9276	C
5609.4982	.4000	214.4746	2878.3314	-3943.8741	C
5676.2847	.5000	218.5152	3570.5430	-5246.5569	C
5722.7922	.6000	221.3289	4168.8288	-6537.3287	C
5785.4462	.8000	225.1195	5155.2558	-9099.3648	C
5826.8482	1.0000	227.6243	5936.9940	-11646.3637	C
5856.7486	1.2000	229.4333	6572.5362	-14184.2597	C
5879.5573	1.4000	230.8132	7099.6266	-16718.9653	C
5897.6253	1.6000	231.9063	7543.9188	-19243.1388	C
5912.3421	1.8000	232.7967	7923.5190	-21766.8191	C
5924.5897	2.0000	233.5377	8251.6014	-24287.7289	C
5986.6699	4.0000	237.2816	10072.3328	-49812.5613	C

M=DOT=GAS/CM = 0,0000 PRESSURE = 1,0000 ATM

TEMP	BPRIM	HCH	TSEN	TCHEM	SPECIE
1950,2530	,1700	48,6791	-254,3202	305,8301	C
2134,5102	,1750	55,5741	-172,4562	212,3615	C
5397,4951	,1800	201,6485	874,9350	-996,1266	C
5773,1326	,1900	224,3745	1102,1274	-1268,9004	C
5931,8822	,2000	233,9789	1256,9256	-1461,5149	C
6110,1626	,2200	244,7648	1514,5038	-1793,8464	C
6262,8777	,2500	254,0041	1848,7836	-2247,4785	C
6413,6138	,3000	263,1236	2338,6896	-2961,3594	C
6511,3070	,3500	269,0341	2775,5082	-3652,7741	C
6583,0252	,4000	273,3730	3172,9050	-4332,7178	C
6685,1946	,5000	279,5543	3875,5512	-5673,5497	C
6756,9142	,6000	2[illegible],8933	4481,1972	-6999,5795	C
6854,3942	,8000	28[illegible],7909	5477,[illegible]42	-9527,5489	C
6919,4282	1,0000	293,7254	6265,3230	-12236,9206	C
6966,7402	1,2000	296,[illegible]878	6904,9476	-14834,9794	C
7003,0458	1,4000	29[illegible],7[illegible]	[illegible],8244	-17425,2806	C
7031,9462	1,6000	300,5327	7881,0462	-20009,8677	C
7055,5846	1,8000	301,9629	8261,9874	-22590,0316	C
7075,3279	2,0000	303,1573	8590,9860	-25166,6433	C
7176,2017	[illegible],0000	309,2602	10412,2944	-50824,4312	C

M=DOT=GAS/CM = 0,0000 PRESSURE = 10,0000 ATM

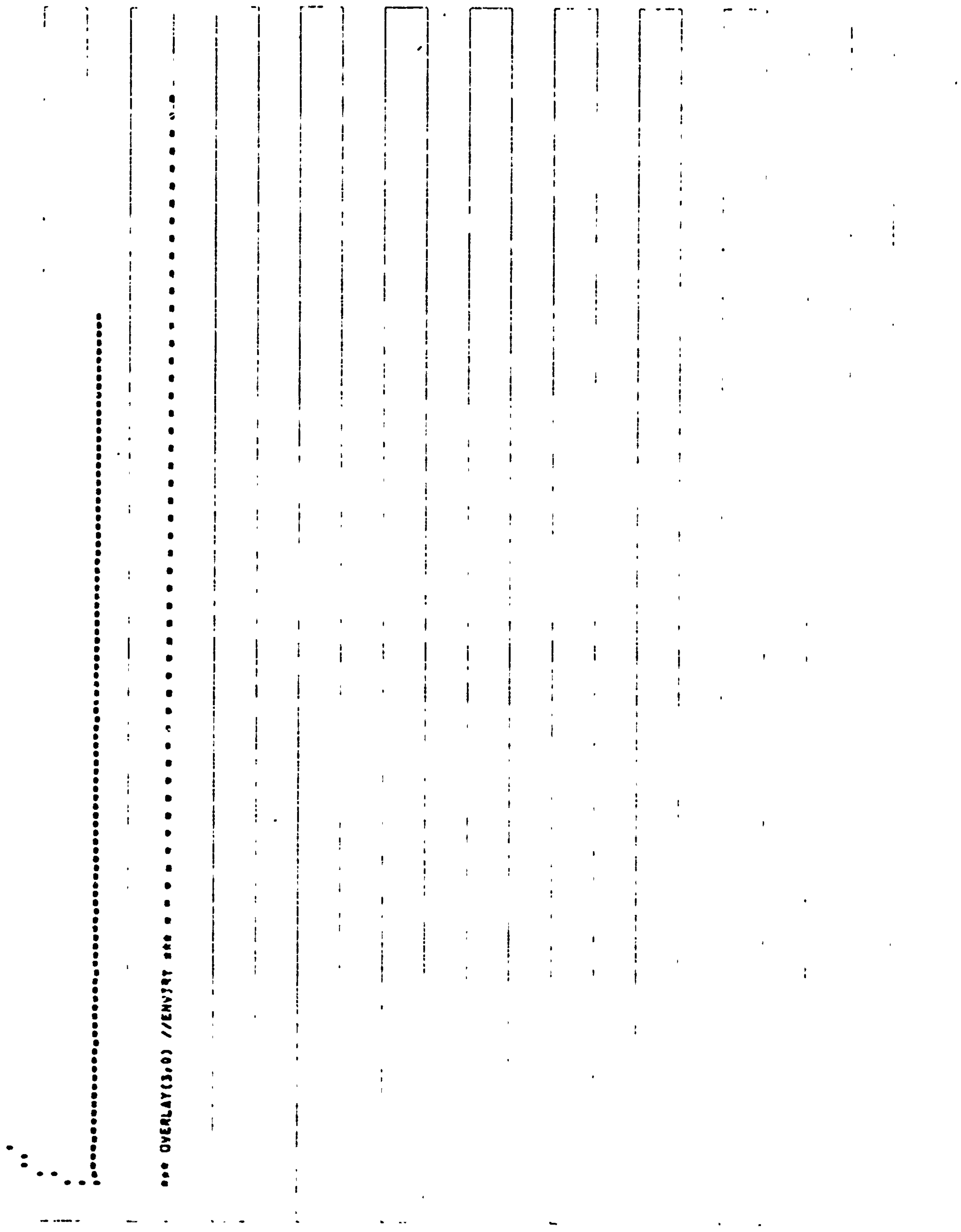
TEMP	BPRIM	HCH	TSEN	TCHEM	SPECIE
2223,0427	,1700	58,8941	-175,8924	215,8061	C
2468,5330	,1750	68,1128	-75,4216	100,5404	C
5701,2169	,1800	220,0236	967,7700	-1102,3643	C
6158,0916	,1900	247,6645	1215,9918	-1399,9740	C
6354,1498	,2000	259,5260	1379,5596	-1603,5663	C
6576,5230	,2200	272,9796	1646,9280	-1949,196[illegible]	C
6768,9353	,2500	284,6206	1989,7974	-2416,0915	C
6960,7312	,3000	296,2242	2488,8888	-3146,6892	C
7086,1318	,3500	303,8110	2932,4592	-3852,4861	C
7178,7929	,4000	309,4170	3335,4558	-4545,3713	C
7311,7577	,5000	317,4613	4047,4188	-5912,3975	C
7405,8219	,6000	323,1522	4660,8210	-7263,4223	C
7534,7032	,8000	330,9495	5669,5806	-9940,4858	C
7621,3771	1,0000	336,1933	6467,2074	-12598,2215	C
7684,7355	1,2000	340,0295	7114,5882	-15244,0586	C
7733,6415	1,4000	342,9853	7650,7398	-17881,5961	C
7772,6554	1,6000	345,3457	8102,1024	-20512,9132	C
7804,6432	1,8000	347,2809	8487,3006	-23139,3360	C
7831,4114	2,0000	348,9004	8819,8850	-25761,7942	C
7968,7883	4,0000	357,2117	10658,1996	-51062,1512	C

M-DOT-GAS/CM = 0.0000   PRESSURE = 100.0000 ATM

TEMP	BPRIM	HCH	TSEN	TCHEM	SPECIE
2589,3241	,1700	72,8236	-68,8698	92,9577	C
2934,6192	,1750	86,2901	62,4384	-58,2643	C
5965,8505	,1800	236,0340	1046,9790	-1192,9491	C
6523,4898	,1900	269,7711	1317,9816	-1517,1416	C
6767,6333	,2000	284,5418	1489,7430	-1730,7832	C
7048,6812	,2200	301,5452	1764,6426	-2086,5240	C
7295,9765	,2500	316,5066	2112,5268	-2561,5319	C
7546,9916	,3000	331,6930	2616,0678	-3301,3802	C
7713,9504	,3500	341,7940	3063,2688	-4015,7850	C
7838,9453	,4000	349,3562	3470,0670	-4718,3513	C
8020,9417	,5000	360,3670	4190,5746	-6105,6784	C
8151,6713	,6000	368,2761	4813,4178	-7480,5028	C
8333,4681	,8000	379,2748	5841,6786	-10211,6016	C
8457,3410	1,0000	386,7691	6657,6942	-12928,6193	C
8548,6450	1,2000	392,2930	7321,4550	-15636,4494	C
8619,2937	1,4000	396,5673	7871,8518	-18337,2501	C
8675,8355	1,6000	399,9880	8335,4904	-21032,2942	C
8722,2384	1,8000	402,7954	8731,2420	-23722,4458	C
8761,0759	2,0000	405,1451	9072,8892	-26408,3778	C
6959,5733	4,0000	417,1542	10957,8726	-53120,7463	C

M-DOT-GAS/CM = 0.0000   PRESSURE = 500.0000 ATM

TEMP	BPRIM	HCH	TSEN	TCHEM	SPECIE
2931,5516	,1700	86,1705	32,6952	-23,6044	C
3390,3725	,1750	104,7101	199,7316	-216,3604	C
6105,5242	,1800	244,4842	1087,9632	-1239,7894	C
6735,8709	,1900	282,6202	1373,1318	-1580,3290	C
7017,0959	,2000	299,6343	1548,7182	-1798,5350	C
7345,3358	,2200	319,4928	1824,6060	-2155,7309	C
7639,1221	,2500	337,2669	2169,5598	-2627,6330	C
7943,5217	,3000	355,6831	2666,7000	-3360,0051	C
8150,3629	,3500	368,1970	3108,8178	-4068,0351	C
8307,9585	,4000	377,7315	3512,4606	-4766,3522	C
8542,2323	,5000	391,9051	4231,9170	-6151,9230	C
8714,3299	,6000	402,3170	4859,0118	-7533,0287	C
8958,9334	,8000	417,1155	5904,7632	-10294,8814	C
9120,5693	1,0000	427,3784	6742,9782	-13058,5780	C
9254,5663	1,2000	435,0013	7429,1022	-15822,0233	C
9352,2463	1,4000	440,9109	8000,1594	-18583,1073	C
9430,3237	1,6000	445,6346	8482,1616	-21340,6048	C
9494,2037	1,8000	449,4993	8893,9538	-24093,9696	C
9547,8626	2,0000	452,7215	9249,5070	-26843,0780	C
9814,8703	4,0000	468,8997	11205,2970	-54150,8864	C


*** OVERLAY(3,0) //ENVIRT ***

```
*** OVERLAY(3,1) //VORT1 *** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

          SHOULDER POINT = 12     SONIC POINT = 9
```

*** STAGNATION POINT ENVIRONMENT HISTORY FOR THE INITIAL BODY SHAPE ***

	- -STAGNATION POINT QUANTITIES- -			- - -FREESTREAM QUANTITIES- - -		
TIME (SEC)	PRESSURE (ATM)	ENTHALPY (BTU/LBM)	HEAT TRANS,COEFF. (LBM/FT2-SEC)	VELOCITY (FT/SEC)	DENSITY (LBM/FT3)	PRESSURE (ATM)
3,9500	1.022E+01	3,297E+02	5,242E-01	3,226E+03	6,997E-02	8,961E-01
4,4500	1.381E+01	4,190E+02	6.271E-01	3,819E+03	6,814E-02	8,672E-01
4,9500	1.514E+01	4,510E+02	6,620E-01	4,063E+03	6,616E-02	8,362E-01
5,2100	1,483E+01	4,490E+02	6,549E-01	4,054E+03	6,509E-02	8,195E-01
5,3500	1.735E+01	5,080E+02	7,250E-01	4.410E+03	6,449E-02	8.102E-01
5,5500	2.106E+01	6,011E+02	8,168E-01	4,900E+03	6,358E-02	7,961E-01
5,7500	2.572E+01	7,170E+02	9,228E-01	5,461E+03	6,259E-02	7,808E-01
6,5200	4,967E+01	1,358E+03	,387E+00	7,884E+03	5,796E-02	7,102E-01
6.6500	5.392E+01	1,486E+03	1,450E+00	8,270E+03	5,707E-02	6,967E-01
6.7500	5.657E+01	1,567E+03	1,495E+00	8,520E+03	5,637E-02	6,861E-01
6,8000	5.693E+01	1,586E+03	1.502E+00	8.575E+03	5,600E-02	6,805E-01
6,8500	5.649E+01	1,584E+03	1,496E+00	,570E+03	5,563E-02	6,750E-01
6,9500	5.591E+01	1,575E+03	1,481E+00	8.545E+03	5,488E-02	6,639E-01
7,0500	5.363E+01	1,552E+03	1.457E+00	8,480E+03	5,415E-02	6,529E-01
7,2500	5.044E+01	1,498E+03	1,404E+00	8,322E+03	5,271E-02	6,316E-01
9,0500	2.540E+01	9,812E+02	9,587E-01	6,583E+03	4,259E-02	4,854E-01
11,0500	1.300E+01	6,463E+02	6,506E-01	5,209E+03	3,506E-02	3,817E-01
14,0500	5,935E+00	4,111E+02	4,119E-01	3,925E+03	2,791E-02	2,888E-01
17,0500	3.105E+00	2,903E+02	2,844E-01	3,119E+03	2,290E-02	2,309E-01

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*** OVERLAY(3,0) //ENVIR1 *** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

*** OVERLAY(3,2) //VORT15 *** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

          NEW CURVE FIT DONE TO BODY POINTS
          3CURVES FIT TO, 10 POINTS
```

CURVE	A	B	C	AUC(I+1)
1	-30,02411E+03	39,18350E+03	18,33200E-17	22,44660E-08
2	-97,00580E+03	39,48680E+03	-34,35280E-02	56,11973E-09
3	-47,35925E+03	38,92965E+03	12,20053E-01	98,77960E-08

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*** OVERLAY(3,3) //VORT3 *** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
```

O U T P U T

****
* VDNT CALLED AT FIRST TIME STEP *
****

TABLE-1 SUMMARY INFORMATION

ITERATION NO. ITS	ITERATION NO. ITS	TIMEP (SEC)	ALTITUDE ALT (FT)	FREESTREAM MACH-NO. M-INF	STAGNATION PT. PRESSURE PT2 (ATM)	STAGNATION PT. ENTHALPY HO (BTU/LBM)
1	0	3.9500	3005	2.921	10.2186	329.7

STAG. PT. RECESSION SPREC (INCH)	CURRENT NOSE RADIUS RN (INCH)	EFFECTIVE NOSE RADIUS R-EFF (INCH)	STAGNATION PT. HEAT TRANS. COEF. SPHTC (LBM/FT**2-SEC)	TRANSITION STREAM LENGTH S-TRAN (INCH)	SONIC PT. AXIAL LENGTH X-STAR (INCH)	SONIC PT. RADIAL LENGTH Y-STAR (INCH)
0.0000	.6478	.6278	.5122	.1292	.1632	.4287

TABLE-3 ENTROPY SWALLOWING INFORMATION

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, L = SHOCK POINT INDEX,
K = SHOCK POINT INDEX FOR STREAMLINE ENTRAINED IN BOUNDARY LAYER AT INTEGRATION POINT I

			* * * * * * BODY GEOMETRY * * * * * * * *					* * * * * * * SHOCK SHAPE * * * * * * *					* ENTROPY SWALLOWING *	
J	I	K	STREAM LENGTH S (INCH)	AXIAL LENGTH X (INCH)	RADIAL LENGTH Y (INCH)	S OVER INPUT RADIUS S/R	BODY ANGLE (DEG)	L	SHOCK AXIAL LENGTH X-SHOCK (INCH)	SHOCK RADIAL LENGTH Y-SHOCK (INCH)	SHOCK ANGLE BETA (DEG)	ENTROPY BEHIND SHOCK SRR	SWALLOWING PARAMETER YBAR (INCH)	EDGE ENTROPY ENTR
1	1	1	0.0000	0.0000	0.0000	0.0000	90.00	1	-.106	0.0000	90.00	24.699	.0010	24.699
2	6	1	.0643	.0332	.0642	.0989	84.32	6	-.1024	.0747	84.66	24.686	.0038	24.699
3	11	1	.1292	.0128	.1284	.1989	78.61	11	-.0911	.1493	79.35	24.649	.0676	24.699
4	16	3	.1955	.0292	.1926	.3007	72.76	16	-.0727	.2242	74.09	24.589	.0379	24.697
5	21	5	.2639	.0529	.2568	.4060	66.73	21	-.0467	.2996	68.92	24.514	.0651	24.691
6	26	7	.3356	.0848	.3210	.5163	60.41	26	-.0122	.3761	63.64	24.425	.0931	24.682
7	31	9	.4121	.1264	.3852	.6340	53.66	31	.0322	.4545	58.33	24.331	.1217	24.668
8	36	11	.4960	.1904	.4494	.7630	46.26	36	.0897	.5362	57.85	24.322	.1503	24.651
9	41	12	.5918	.2516	.5136	.9105	37.80	41	.2958	.8226	47.37	24.164	.1779	24.632
10	46	14	.7112	.3523	.5778	1.0942	27.26	46	.6756	1.1675	36.30	23.884	.2022	24.612
11	49	16	.9175	.5483	.6420	1.4116	15.47	49	1.7494	1.8302	26.01	23.646	.2263	24.598
12	51	18	1.4183	1.0429	.7203	2.1820	9.00	51	4.5149	3.1045	21.93	23.646	.2686	24.568
13	53	20	1.9191	1.5376	.7987	2.9525	9.00	53	7.4693	4.2942	21.93	23.646	.2993	24.529
14	55	22	2.4199	2.0322	.8770	3.7229	9.00	55	8.6115	4.7542	21.93	23.646	.3262	24.499
15	57	24	2.9207	2.5268	.9554	4.4934	9.00	57	9.7537	5.2142	21.93	23.646	.3522	24.469
16	59	26	3.4215	3.0214	1.0337	5.2639	9.00	59	10.8959	5.6741	21.93	23.646	.3775	24.439
17	61	27	3.9223	3.5161	1.1120	6.0343	9.00	61	12.0361	6.1341	21.93	23.646	.4023	24.408
18	63	29	4.4230	4.0107	1.1904	6.8048	9.00	63	13.1804	6.5941	21.93	23.646	.4267	24.379
19	65	30	4.9238	4.5053	1.2687	7.5752	9.00	65	14.3226	7.0540	21.93	23.646	.4507	24.350
20	67	32	5.4246	4.9999	1.3471	8.3457	9.00	67	15.4648	7.5140	21.93	23.652	.4743	24.321

TABLE-4 BOUNDARY CONDITIONS

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, NTB = TRANSITION FLAG

J	I	NTB	STREAM LENGTH S (INCH)	PRESSURE RATIO PE/PT2	EDGE MACH NO. ME	EDGE ENTHALPY HE (BTU/LBM)	EDGE TEMP TE (R)	EDGE DENSITY RHOE (LBM/FT3)	EDGE VELOCITY VEL (FT/SEC)	EDGE VISC. UE (LBM/FT-SEC)	EDGE REYNOLDS NO. RE-EDGE (1/FT)	RECOVERY TEMP. TR (R)	RECOVERY ENTHALPY HR (BTU/LBM)	WALL TEMP TW (R)	WALL ENTHALPY HW (BTU/LBM)
			BOUNDARY LAYER EDGE PROPERTIES									RECOVERY CONDITIONS		WALL CONDITIONS	
1	1	-1	0.0000	1.0000	0.0000	329.7	1333.5	3.038E-01	0.0	2.344E-05	0.	1333.5	329.7	540.0	129.7
2	6	-1	.0643	.9996	.1257	328.9	1330.1	3.014E-01	208.4	2.340E-05	2.684E+06	1333.0	329.6	540.0	129.7
3	11	0	.1292	.9589	.2517	326.3	1320.0	2.943E-01	415.0	2.329E-05	5.244E+06	1331.4	329.2	540.0	129.7
4	16	1	.1955	.9083	.3874	321.8	1302.1	2.826E-01	634.2	2.309E-05	7.763E+06	1330.0	328.9	540.0	129.7
5	21	1	.2639	.8387	.5338	315.3	1275.1	2.665E-01	864.9	2.278E-05	1.012E+07	1327.2	328.2	540.0	129.7
6	26	2	.3356	.7519	.6947	306.4	1237.5	2.462E-01	1108.8	2.235E-05	1.221E+07	1323.1	327.2	540.0	129.7
7	31	2	.4121	.6507	.8745	294.6	1187.5	2.220E-01	1367.3	2.177E-05	1.394E+07	1317.7	325.9	540.0	129.7
8	36	2	.4960	.5012	1.0772	279.6	1123.8	1.951E-01	1638.4	2.101E-05	1.522E+07	1310.8	324.3	540.0	129.7
9	41	2	.5918	.4165	1.3310	258.6	1037.7	1.626E-01	1945.6	1.994E-05	1.587E+07	1301.5	322.0	540.0	129.7
10	46	2	.7112	.2791	1.6891	226.8	913.5	1.238E-01	2316.4	1.831E-05	1.566E+07	1288.1	318.6	540.0	129.7
11	49	2	.9175	.1526	2.1494	188.2	762.7	8.107E-02	2693.4	1.616E-05	1.351E+07	1271.9	314.5	540.0	129.7
12	51	2	1.4183	.1100	2.3525	174.6	701.5	6.355E-02	2827.1	1.522E-05	1.180E+07	1265.2	313.0	540.0	129.7
13	53	2	1.9191	.1100	2.3736	174.6	695.4	6.411E-02	2840.1	1.513E-05	1.204E+07	1264.6	313.0	540.0	129.7
14	55	2	2.4199	.1100	2.3911	174.5	690.4	6.457E-02	2850.7	1.505E-05	1.223E+07	1264.0	313.0	540.0	129.7
15	57	2	2.9207	.1100	2.4094	174.5	685.2	6.506E-02	2861.7	1.497E-05	1.244E+07	1263.5	313.0	540.0	129.7
16	59	2	3.4215	.1100	2.4282	174.5	679.9	6.557E-02	2872.8	1.488E-05	1.266E+07	1262.9	313.0	540.0	129.7
17	61	2	3.9223	.1100	2.4468	174.4	674.7	6.607E-02	2883.7	1.480E-05	1.287E+07	1262.3	313.0	540.0	129.7
18	63	2	4.4230	.1100	2.4648	174.4	669.7	6.657E-02	2894.2	1.472E-05	1.309E+07	1261.8	313.0	540.0	129.7
19	65	2	4.9238	.1100	2.4829	174.3	664.7	6.707E-02	2904.6	1.464E-05	1.331E+07	1261.3	313.0	540.0	129.7
20	67	2	5.4246	.1100	2.5015	174.3	659.6	6.758E-02	2915.1	1.456E-05	1.353E+07	1260.7	312.9	540.0	129.7

TABLE-5 HEAT TRANSFER AND BOUNDARY LAYER QUANTITIES

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, NTB = TRANSITION FLAG

J	I	NTB	STREAM LENGTH S (INCH)	NON-BLOWN HEAT FLUX QDOT (BTU/ FT2-SEC)	HEAT TRANS. COEF. BASED ON TR HTC (BTU/ FT2-SEC-R)	HEAT TRANS. COEF. BASED ON HR CHO (LBM/ FT2-SEC)	LAMINAR HEATING PARAMETER FL	TURBULENT HEATING PARAMETER FT	WEIGHTING PARAMETER FFT	NET HEATING PARAMETER FCHT	LAMINAR MOMENTUM THICKNESS THETA-LAM (MIL)	DISPLACE-MENT THICKNESS DELSTR (MIL)	LAMINAR MOMENTUM REYN. NO. RETHL
1	1	-1	0,0000	1,0287E+02	1,2916E-01	,5122	1,0000	1,0000	0,0000	1,0000	,170	,087	0,00
2	6	-1	,0643	1,0121E+02	1,2764E-01	,5062	,9882	1,3187	0,0000	,9882	,172	,088	38,45
3	11	0	,1292	9,8363E+01	1,2429E-01	,4930	,9624	1,8215	0,0000	,9624	,176	,092	76,76
4	16	1	,1955	3,6489E+02	4,6137E-01	1,8298	,9272	3,8847	,9414	3,5721	,181	,097	115,43
5	21	1	,2639	4,4417E+02	5,6428E-01	2,2375	,8787	4,4550	,9879	4,3680	,188	,106	154,86
6	26	2	,3356	4,8024E+02	6,1323E-01	2,4309	,8160	4,7842	,9954	4,7455	,199	,119	195,57
7	31	2	,4121	4,8580E+02	6,2464E-01	2,4750	,7376	4,8523	,9977	4,8316	,215	,140	236,41
8	36	2	,4960	4,6286E+02	6,0045E-01	2,3778	,6470	4,6538	,9987	4,6419	,238	,172	284,75
9	41	2	,5918	4,0715E+02	5,3464E-01	2,1163	,5355	4,1383	,9992	4,1315	,274	,229	339,36
10	46	2	,7112	3,1222E+02	4,1733E-01	1,6524	,4042	3,2243	,9995	3,2257	,337	,350	415,10
11	49	2	,9175	1,6707E+02	2,2828E-01	,9041	,2292	1,7664	,9996	1,7650	,507	,695	540,59
12	51	2	1,4183	7,0499E+01	9,7207E-02	,3846	,1416	,7514	,9995	,7507	,738	1,141	675,12
13	53	2	1,9191	6,7753E+01	9,3509E-02	,3696	,1217	,7222	,9995	,7215	,803	1,257	735,27
14	55	2	2,4199	6,5686E+01	9,0722E-02	,3583	,1138	,7001	,9995	,6995	,860	1,359	787,31
15	57	2	2,9207	6,4123E+01	8,8631E-02	,3498	,1075	,6834	,9996	,6829	,910	1,454	833,84
16	59	2	3,4215	6,2893E+01	8,7000E-02	,3431	,1023	,6703	,9996	,6698	,956	1,544	876,35
17	61	2	3,9223	6,1886E+01	8,5674E-02	,3376	,0979	,6596	,9996	,6591	,999	1,631	915,84
18	63	2	4,4230	6,1033E+01	8,4556E-02	,3330	,0942	,6505	,9996	,6500	1,039	1,714	952,95
19	65	2	4,9238	6,0311E+01	8,3618E-02	,3290	,0909	,6428	,9997	,6424	1,076	1,794	988,14
20	67	2	5,4246	5,9703E+01	8,2838E-02	,3257	,0879	,6363	,9997	,6359	1,112	1,874	1021,72

TABLE-6 ROUGHNESS HEATING QUANTITIES

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, NTB = TRANSITION FLAG

J	I	NTB	STREAM LENGTH S (INCH)	LAMINAR ROUGH STANT NO. STANTL	COMPOSITE ROUGH STANT NO. STANTT	COMPOSITE SMOOTH STANT NO. STANTS	TRANSITION ROUGH STANT NO. STANTN	ROUGHNESS HEIGHT K (MIL)	DELSTR TRANSITION PARAMETER	THEATA TRANSITION PARAMETER	TURBULENT ROUGHNESS HEATING PARAMETER	NET ROUGHNESS HEATING FACTOR	TURBULENT MOMENTUM REYN. NO. RETHT
1	1	-1	0.0000	0.	0.	0.	0.	.40	0.000	0.	0.	1.000	0.
2	6	-1	.0643	8.0593E-03	1.0727E-02	8.9874E-03	8.0593E-03	.40	805.210	1.3053E+02	2.7381E+01	1.000	5.5051E+01
3	11	0	.1292	4.0365E-03	7.6079E-03	5.6445E-03	4.0365E-03	.40	1959.986	2.5530E+02	4.1977E+01	1.000	1.6478E+02
4	16	1	.1955	2.6497E-03	1.1093E-02	4.5338E-03	1.0208E-02	20.00	3265.818	5.7618E+03	2.7356E+03	2.362	4.5963E+02
5	21	1	.2639	1.9525E-03	9.8975E-03	3.9116E-03	9.7071E-03	20.00	4570.044	7.4012E+03	3.2222E+03	2.512	8.9666E+02
6	26	2	.3356	1.5313E-03	8.9764E-03	3.4801E-03	8.9052E-03	20.00	5743.622	8.7994E+03	3.5285E+03	2.572	1.4229E+03
7	31	2	.4121	1.2446E-03	8.1868E-03	3.1431E-03	8.1527E-03	20.00	6659.444	9.8806E+03	3.6293E+03	2.601	2.0236E+03
8	36	2	.4960	1.0367E-03	7.4566E-03	2.8571E-03	7.4380E-03	20.00	7212.781	1.0577E+04	3.5150E+03	2.608	2.6952E+03
9	41	2	.5918	8.6705E-04	6.7008E-03	2.5860E-03	6.6900E-03	20.00	7255.713	1.0816E+04	3.1433E+03	2.590	3.4395E+03
10	46	2	.7112	7.2203E-04	5.7482E-03	2.2915E-03	5.7619E-03	18.62	6611.914	9.9414E+03	2.3041E+03	2.315	4.2737E+03
11	49	2	.9175	5.3771E-04	4.1437E-03	1.9547E-03	4.1404E-03	6.85	4942.410	4.2626E+03	5.3465E+02	2.119	5.4261E+03
12	51	2	1.4183	4.0367E-04	2.1424E-03	1.7336E-03	2.1406E-03	.40	4230.196	5.2821E+02	2.3017E+01	1.236	7.1626E+03
13	53	2	1.9191	3.4247E-04	2.0318E-03	1.6498E-03	2.0301E-03	.40	4619.395	5.3876E+02	2.2640E+01	1.231	8.0207E+03
14	55	2	2.4199	3.1657E-04	1.9482E-03	1.5863E-03	1.9467E-03	.40	4941.716	5.4733E+02	2.2352E+01	1.228	8.6886E+03
15	57	2	2.9207	2.9566E-04	1.8803E-03	1.5341E-03	1.8789E-03	.40	5231.798	5.5409E+02	2.2136E+01	1.226	9.3220E+03
16	59	2	3.4215	2.7817E-04	1.8229E-03	1.4896E-03	1.8216E-03	.40	5499.925	5.5956E+02	2.1970E+01	1.224	9.9309E+03
17	61	2	3.9223	2.6324E-04	1.7732E-03	1.4509E-03	1.7720E-03	.40	5750.093	5.6415E+02	2.1834E+01	1.222	1.0522E+04
18	63	2	4.4230	2.5040E-04	1.7295E-03	1.4166E-03	1.7283E-03	.40	5984.922	5.6814E+02	2.1725E+01	1.221	1.1098E+04
19	65	2	4.9238	2.3894E-04	1.6902E-03	1.3857E-03	1.6892E-03	.40	6209.919	5.7158E+02	2.1632E+01	1.220	1.1664E+04
20	67	2	5.4246	2.2859E-04	1.6548E-03	1.3573E-03	1.6534E-03	.40	6429.191	5.7446E+02	2.1558E+01	1.219	1.2222E+04

.40000000 10.21858604 1333.49611803 14803378.74508387 7

*** OVERLAY(4,0) //THERMS ***

ALTINF,VINF,ROINF,RP,CZ/FT,FT/SEC,LB/FT3,FT,LB/FT3
3.0050E+03 3.2260E+03 6.9973E-02 1.6514E-03 1.1318E-05

\+ DENOTES 15 ITERATIONS ON DELTA-98 LOOP
G DENOTES GRAPHITE
* DENOTES TUNGSTEN

NN	GV	GEFF	RTIL	ROBAR	EFFK	TUBS	GCM	TST	DFIFL	DOB(MM)	PVM
1G	0.	3.2882E+00	0.	0.	2.5092E-03	0.	0.	0.	0.	0.	0.
2G	0.	3.2781E+00	0.	0.	2.5067E-03	0.	0.	0.	0.	0.	0.
3G	0.	3.2478E+00	0.	0.	2.4989E-03	0.	0.	0.	0.	0.	0.
4G	0.	3.1958E+00	0.	0.	2.4855E-03	0.	0.	0.	0.	0.	0.
5G	0.	3.1196E+00	0.	0.	2.4656E-03	0.	0.	0.	0.	0.	0.
6G	0.	3.0152E+00	0.	0.	2.4378E-03	0.	0.	0.	0.	0.	0.
7G	0.	2.8755E+00	0.	0.	2.3995E-03	0.	0.	0.	0.	0.	0.
8G	0.	2.6880E+00	0.	0.	2.3462E-03	0.	0.	0.	0.	0.	0.
9G	0.	2.4274E+00	0.	0.	2.2678E-03	0.	0.	0.	0.	0.	0.
10G	0.	2.0264E+00	0.	0.	2.1354E-03	0.	0.	0.	0.	0.	0.
11G	0.	1.4492E+00	0.	0.	1.9096E-03	0.	0.	0.	0.	0.	0.
12G	0.	1.0410E+00	0.	0.	1.7102E-03	0.	0.	0.	0.	0.	0.
13G	0.	1.0410E+00	0.	0.	1.7102E-03	0.	0.	0.	0.	0.	0.
14G	0.	1.0410E+00	0.	0.	1.7102E-03	0.	0.	0.	0.	0.	0.
15G	0.	1.0410E+00	0.	0.	1.7102E-03	0.	0.	0.	0.	0.	0.
16G	0.	1.0410E+00	0.	0.	1.7102E-03	0.	0.	0.	0.	0.	0.
17G	0.	1.0410E+00	0.	0.	1.7102E-03	0.	0.	0.	0.	0.	0.
18G	0.	1.0410E+00	0.	0.	1.7102E-03	0.	0.	0.	0.	0.	0.
19G	0.	1.0410E+00	0.	0.	1.7102E-03	0.	0.	0.	0.	0.	0.
20G	0.	1.0410E+00	0.	0.	1.7102E-03	0.	0.	0.	0.	0.	0.

BODY POINT LOCATIONS AND SURFACE ENERGY BALANCE RESULTS AT
TIME = 4,1500 SEC

* DENOTES ANGLE LIMIT

POINT NUMBER	Z (INCHES)	Z-DOT USED	WALL TEMPERATURE (DEG R)	S-DOT TOTAL (IN/SEC)	S-DOT EROSION (IN/SEC)	PARTICLE ROUGHNESS (MILS)	B-PRIME THERMO-CHEM	CHH	CH (LBM/FT**2-SEC)	CHZ
1	,00424	,02119	2976,87	21,1895E-03	12,3135E-03	30,1108E+00	17,5772E-02	99,3229E+00	49,2346E-02	,51224
2	,00740	,02109	2974,49	20,9870E-03	12,2157E-03	30,0801E+00	17,5771E-02	98,0865E+00	48,6547E-02	,50621
3	,01698	,02088	2969,15	20,4648E-03	11,9229E-03	29,9872E+00	17,5770E-02	95,3280E+00	47,3819E-02	,49297
4	,03866	,04736	3149,84	45,2360E-03	11,4303E-03	29,8262E+00	17,6059E-02	37,6037E+01	18,7214E-01	1,82977
5	,06425	,05684	3161,89	52,2144E-03	10,7321E-03	29,5674E+00	17,6094E-02	45,9754E+01	22,9679E-01	2,23749
6	,09742	,06316	3164,04	54,9169E-03	98,1840E-04	29,2535E+00	17,6121E-02	49,7371E+01	24,9663E-01	2,43087
7	,13999	,06779	3161,23	54,6054E-03	86,7358E-04	28,7945E+00	17,6149E-02	50,3242E+01	25,4237E-01	2,47498
8	,19461	,07116	3154,16	51,4111E-03	72,7261E-04	28,1547E+00	17,6178E-02	47,9548E+01	24,4271E-01	2,37779
9	,26624	,07320	3140,62	46,8660E-03	55,7146E-04	27,2138E+00	17,6214E-02	42,1893E+01	21,7419E-01	2,11632
10	,36717	,07459	3118,49	34,1651E-03	34,7602E-04	25,6244E+00	17,6261E-02	32,3583E+01	16,9759E-01	1,65237
11	,56199	,06839	3050,00	18,2424E-03	14,4759E-04	22,9153E+00	17,6293E-02	17,3185E+01	92,8851E-02	,90409
12	1,05284	,04953	2925,91	77,4872E-04	60,9820E-05	20,5227E+00	17,6174E-02	73,0829E+00	39,5087E-02	,38457
13	1,54711	,04776	2918,69	74,7057E-04	60,9820E-05	20,5227E+00	17,6164E-02	70,2385E+00	37,9717E-02	,36961
14	2,04146	,04602	2912,95	72,6093E-04	60,9820E-05	20,5227E+00	17,6155E-02	68,0942E+00	36,8133E-02	,35833
15	2,53588	,04540	2908,42	71,0250E-04	60,9820E-05	20,5227E+00	17,6148E-02	66,4733E+00	35,9378E-02	,34981
16	3,03035	,04461	2904,73	69,7798E-04	60,9820E-05	20,5227E+00	17,6142E-02	65,1992E+00	35,2497E-02	,34311
17	3,52484	,04395	2901,63	68,7596E-04	60,9820E-05	20,5227E+00	17,6138E-02	64,1551E+00	34,6859E-02	,33762
18	4,01935	,04340	2898,94	67,8957E-04	60,9820E-05	20,5227E+00	17,6133E-02	63,2706E+00	34,2085E-02	,33297
19	4,51388	,04293	2896,62	67,1650E-04	60,9820E-05	20,5227E+00	17,6130E-02	62,5222E+00	33,8047E-02	,32904
20	5,00843	,04254	2894,63	66,5500E-04	60,9820E-05	20,5227E+00	17,6127E-02	61,8921E+00	33,4648E-02	,32573

TOTAL STAGNATION POINT RECESSION DUE TO EROSION ONLY = ,0025 INCHES

*** OVERLAY(3,0) //ENVIRI *** •

*** OVERLAY(3,1) //VORT1 *** •

SHOULDER POINT = 12 SONIC POINT = 9

*** OVERLAY(3,2) //VORT1S *** •

*** OVERLAY(3,3) //VORT3 *** •

****
* VORT CALLED AT SPECIFIED OUTPUT TIME *
****

TABLE-1 SUMMARY INFORMATION

ITERATION NO. ITS	ITERATION NO. ITS	TIMEP (SEC)	ALTITUDE ALT (FT)	FREESTREAM MACH-NO. M-INF	STAGNATION PT. PRESSURE PT2 (ATM)	STAGNATION PT. ENTHALPY HO (BTU/LBM)
39	0	16,6500	34748	3,287	3,4056	304,2

STAG. PT. RECESSION SPREC (INCH)	CURRENT NOSE RADIUS RN (INCH)	EFFECTIVE NOSE RADIUS R-EFF (INCH)	STAGNATION PT. HEAT TRANS. COEF. SPHTC (LBM/FT**2-SEC)	TRANSITION STREAM LENGTH S-TRAN (INCH)	SONIC PT. AXIAL LENGTH X-STAR (INCH)	SONIC PT. RADIAL LENGTH Y-STAR (INCH)
1,0065	,5014	,2546	,4391	,0771	1,1925	,5037

TABLE-3 ENTROPY SWALLOWING INFORMATION

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, L = SHOCK POINT INDEX,
K = SHOCK POINT INDEX FOR STREAMLINE ENTRAINED IN BOUNDARY LAYER AT INTEGRATION POINT I

			* * * * * * * BODY GEOMETRY * * * * * * * *						* * * * * * SHOCK SHAPE * * * * * *				* ENTROPY SWALLOWING *	
J	I	K	STREAM LENGTH S (INCH)	AXIAL LENGTH X (INCH)	RADIAL LENGTH Y (INCH)	S OVER INPUT RADIUS S/R	BODY ANGLE (DEG)	L	SHOCK AXIAL LENGTH X-SHOCK (INCH)	SHOCK RADIAL LENGTH Y-SHOCK (INCH)	SHOCK ANGLE BETA (DEG)	ENTROPY BEHIND SHOCK SRB	SWALLOWING PARAMETER YBAR (INCH)	EDGE ENTROPY ENTR
1	1	1	0,0000	1,0065	0,0000	0,0000	90,00	1	,8908	0,0000	90,00	25,498	,0015	25,498
2	9	1	,0642	1,0087	,0642	,0988	72,49	9	,9063	,0965	73,84	25,385	,0061	25,497
3	17	2	,1408	1,0505	,1264	,2166	56,98	17	,9490	,1943	60,95	25,180	,0188	25,493
4	33	3	,2050	1,0527	,1926	,3154	88,00	33	,9492	,1962	88,12	25,496	,0279	25,488
5	45	3	,2714	1,0694	,2568	,4175	63,74	45	,9756	,3030	66,44	25,274	,0359	25,482
6	53	5	,3570	1,1261	,3210	,5492	48,56	53	1,0341	,4022	54,36	25,068	,0518	25,467
7	73	6	,4212	1,1283	,3852	,6481	88,00	73	1,0341	,4022	54,36	25,068	,0658	25,445
8	85	7	,4868	1,1418	,4494	,7490	64,91	85	1,0569	,4891	67,42	25,290	,0756	25,429
9	93	8	,5745	1,2015	,5136	,8839	47,07	93	1,1178	,5914	53,29	25,051	,0898	25,403
10	98	9	,6589	1,2562	,5778	1,0137	49,56	98	1,1642	,6562	55,08	25,080	,1077	25,371
11	106	10	,7595	1,3337	,6420	1,1685	33,95	106	1,4431	,9932	41,84	24,666	,1180	25,345
12	118	12	1,1436	1,7098	,7203	1,7595	10,97	118	4,6863	2,7440	21,45	24,303	,1374	25,305
13	120	13	1,5931	2,1524	,7987	2,4510	9,91	120	6,6735	3,5202	20,82	24,089	,1527	25,289
14	122	14	2,0547	2,6073	,8770	3,1611	9,68	122	8,0136	4,0290	20,63	24,108	,1682	25,256
15	124	16	2,5251	3,0710	,9554	3,8848	9,53	124	9,1076	4,4415	20,59	24,110	,1837	25,221
16	126	33	3,0015	3,5410	1,0337	4,6178	9,41	126	10,1922	4,8485	[illegible],52	24,111	,1993	25,186
17	128	35	3,4837	4,0168	1,1120	5,3596	9,31	128	11,2820	5,2561	2[illegible],46	24,111	,2233	25,481
18	130	37	3,9705	4,4972	1,1904	6,1085	9,23	130	12,3763	5,6640	20,41	24,111	,2385	25,460
19	132	39	4,4609	4,9814	1,2687	6,8631	9,17	132	13,4659	6,0693	20,38	24,111	,2535	25,432
20	134	40	4,9540	5,4682	1,3471	7,6217	9,12	134	14,5517	6,4728	20,35	24,111	,2682	25,398

TABLE=4 BOUNDARY CONDITIONS

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, NTB = TRANSITION FLAG

J	I	NTB	STREAM LENGTH S (INCH)	PRESSURE RATIO PE/PT2	EDGE MACH NO, ME	EDGE ENTHALPY HE (BTU/LBM)	EDGE TEMP TE (R)	EDGE DENSITY RHOE (LBM/FT3)	EDGE VELOCITY VEL (FT/SEC)	EDGE VISC, UE (LBM/FT-SEC)	EDGE REYNOLDS NO, RE-EDGE (1/FT)	RECOVERY TEMP, TR (R)	RECOVERY ENTHALPY HR (BTU/LBM)	WALL TEMP TW (R)	WALL ENTHALPY HW (BTU/LBM)
			BOUNDARY LAYER EDGE PROPERTIES									RECOVERY CONDITIONS		WALL CONDITIONS	
1	1	-1	0,0000	1,0000	0,0000	304,2	1238,3	1,090E-01	0,0	2,236E-05	0,	1238,3	30C,2	2983,3	785,4
2	9	-1	,0662	,9802	,3047	299,1	1218,4	1,042E-01	482,6	2,213E-05	2,272E+06	1235,2	303,4	2961,7	779,1
3	17	2	,1408	,7940	,6321	285,2	1163,6	9,219E-02	978,3	2,149E-05	4,197E+06	1230,3	302,2	3022,0	796,7
4	33	2	,2050	,9587	,1844	303,0	1231,6	1,084E-01	293,7	2,229E-05	1,428E+06	1237,6	304,1	2805,2	733,5
5	45	2	,2714	,8450	,5562	290,0	1179,7	9,672E-02	865,7	2,168E-05	3,867E+06	1232,0	302,7	2994,1	788,5
6	53	2	,3570	,6543	,8915	270,1	1098,0	8,170E-02	1340,4	2,069E-05	5,292E+06	1223,2	300,5	2994,4	788,6
7	73	2	,4212	,9011	,4324	298,4	1202,2	1,057E-01	680,2	2,194E-05	3,277E+06	1234,4	303,6	2932,8	770,6
8	85	2	,4868	,7962	,7165	284,5	1143,9	9,398E-02	1099,5	2,125E-05	4,862E+06	1228,1	302,1	2983,0	785,3
9	93	2	,5745	,5545	1,1335	256,1	1026,3	7,427E-02	1647,6	1,979E-05	6,182E+06	1215,4	299,0	2975,0	783,0
10	98	2	,6589	,6086	1,0905	261,9	1039,5	7,906E-02	1595,4	1,996E-05	6,318E+06	1216,9	299,6	2976,8	783,5
11	106	2	,7595	,3600	1,6023	218,8	876,0	5,549E-02	2151,7	1,779E-05	6,711E+06	1199,2	295,0	2916,1	765,7
12	118	2	1,1436	,1036	2,4274	157,7	629,8	2,220E-02	2764,0	1,407E-05	4,362E+06	1172,6	288,4	2499,3	646,0
13	120	2	1,5931	,0974	2,4789	155,0	616,5	2,133E-02	2792,8	1,385E-C5	4,301E+06	1171,2	288,1	2476,6	639,6
14	122	2	2,0547	,0962	2,5105	154,3	608,5	2,134E-02	2810,C	1,372E-05	4,372E+06	1170,3	288,0	2468,8	637,4
15	124	2	2,5251	,0953	2,5406	153,7	601,0	2,142E-02	2826,0	1,359E-05	4,455E+06	1169,5	288,0	2463,1	635,7
16	126	2	3,0015	,0947	2,5692	153,1	594,0	2,153E-02	2841,1	1,347E-05	4,542E+06	1168,7	287,9	2445,2	630,7
17	128	2	3,4837	,0942	2,3740	152,6	643,8	1,975E-02	2733,2	1,430E-05	3,776E+06	1174,1	287,8	2439,4	629,1
18	130	2	3,9705	,0938	2,3906	152,1	639,4	1,980E-02	2742,9	1,423E-05	3,818E+06	1173,7	287,8	2435,9	628,1
19	132	2	4,4609	,0935	2,4111	151,6	634,0	1,991E-02	2754,7	1,414E-05	3,878E+06	1173,1	287,7	2433,3	627,3
20	134	2	4,9540	,0932	2,4358	151,2	627,7	2,005E-02	2768,5	1,404E-05	3,956E+06	1172,4	287,7	2431,4	626,8

TABLE-5 HEAT TRANSFER AND BOUNDARY LAYER QUANTITIES

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, NTB = TRANSITION FLAG

J	I	NTB	STREAM LENGTH S (INCH)	NON-BLOWN HEAT FLUX QDOT (BTU/ FT2-SEC)	HEAT TRANS. COEF. BASED ON TP HTC (BTU/ FT2-SEC-R)	HEAT TRANS. COEF. BASED ON HR CHO (LBM/ FT2-SEC)	LAMINAR HEATING PARAMETER FL	TURBULENT HEATING PARAMETER FT	WEIGHTING PARAMETER FFT	NET HEATING PARAMETER FCHT	LAMINAR MOMENTUM THICKNESS THETA-LAM (MIL)	DISPLACEMENT THICKNESS DELSTR (MIL)	LAMINAR MOMENTUM REYN. NO. RETHL
1	1	-1	0.0000	-2.2476E+02	1.2881E-01	.4671	1.0638	1.0638	0.0000	1.0638	.049	.307	0.00
2	9	-1	.0642	-2.0399E+02	1.1612E-01	.4288	.9764	.9882	0.0000	.9764	.053	.334	10.11
3	17	2	.1408	-2.7490E+02	1.5345E-01	.5559	.6290	1.2660	1.0000	1.2660	.067	.451	19.94
4	33	2	.2050	-7.3922E+01	4.7157E-02	.1721	.2738	.3920	1.0000	.3920	.198	1.155	25.69
5	45	2	.2714	-2.1710E+02	1.2321E-01	.4468	.6644	1.0176	1.0000	1.0176	.077	.507	23.96
6	53	2	.3570	-2.2949E+02	1.2957E-01	.4772	.4214	1.0707	1.0000	1.0707	.098	.698	36.30
7	73	2	.4312	-1.4125E+02	8.3170E-02	.30[illegible]	.3149	.6888	1.0000	.6888	.151	.950	37.68
8	85	2	.4868	-2.0150E+02	1.1482E-01	.4110	.4199	.9496	1.0000	.9496	.121	.821	39.00
9	93	2	.5745	-2.0469E+02	1.1633E-01	.4230	.4284	.9632	1.0000	.9632	.110	.834	49.50
10	98	2	.6589	-2.0347E+02	1.1561E-01	.4205	.4970	.9577	1.0000	.9577	.091	.684	55.96
11	106	2	.7595	-1.5139E+02	8.8177E-02	.3216	.2711	.7323	1.0000	.7323	.146	1.290	77.62
12	118	2	1.1036	-2.5445E+01	1.9180E-02	.0712	.0734	.1620	1.0000	.1620	.625	6.642	172.58
13	120	2	1.5931	-2.3320E+01	1.7864E-02	.0669	.0695	.1511	1.0000	.1511	.659	7.099	184.92
14	122	2	2.0547	-2.2613E+01	1.74[illegible]E-02	.0647	.0682	.1474	1.0000	.1474	.669	7.282	194.66
15	124	2	2.5251	-2.2117E+01	1.7098E-02	.0636	.0666	.1448	1.0000	.1448	.682	7.504	204.99
16	126	2	3.0015	-2.1575E+01	1.6902E-02	.0629	.0646	.1433	1.0000	.1433	.705	7.786	217.58
17	128	2	3.4837	-2.0229E+01	1.5988E-02	.0593	.0624	.1350	1.0000	.1350	.725	7.334	228.77
18	130	2	3.9705	-1.[illegible]755E+01	1.5809E-02	.0586	.0600	.1335	1.000	.1335	.746	7.596	239.67
19	132	2	4.4609	-1.[illegible]752E+01	1.5674E-02	.0582	.0573	.1325	1.0000	.1325	.770	7.899	250.27
20	134	2	4.9540	-1.9602E+01	1.5569E-02	.0578	.0538	.1316	1.0000	.1316	.798	8.267	260.47

TABLE-4 ROUGHNESS HEATING QUANTITIES

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, NTB = TRANSITION FLAG

J	I	NTB	STREAM LENGTH S (INCH)	LAMINAR ROUGH STANT NO. STANTL	COMPOSITE ROUGH STANT NO. STANTT	COMPOSITE SMOOTH STANT NO. STANTS	TRANSITION ROUGH STANT NO. STANTN	ROUGHNESS HEIGHT K (MIL)	DELSTR TRANSITION PARAMETER	THEATA TRANSITION PARAMETER	TURBULENT ROUGHNESS HEATING PARAMETER	NET ROUGHNESS HEATING FACTOR	TURBULENT MOMENTUM REYN. NO. RETHT
1	1	-1	0.0000	0.	0.	0.	0.	.40	0.000	0.	0.	1.064	0.
2	9	-1	.0642	8.5262E-03	8.2312E-03	8.0428E-03	8.5262E-03	.40	436.960	2.2229E+01	2.1405E+00	1.043	4.0851E+01
3	17	2	.1408	3.0627E-03	6.1643E-03	3.9901E-03	6.1643E-03	20.00	949.205	5.5263E+02	1.2784E+02	1.543	1.1776E+02
4	33	2	.2050	3.7763E-03	5.4071E-03	3.9544E-03	5.4071E-03	20.00	267.585	3.6504E+02	5.1346E+01	1.367	1.5497E+02
5	45	2	.2714	3.4803E-03	5.3302E-03	3.3794E-03	5.3302E-03	20.00	1046.886	6.1091E+02	1.1163E+02	1.577	1.9535E+02
6	53	2	.3570	1.6897E-03	4.2935E-03	2.5418E-03	4.2935E-03	20.00	1410.526	7.4288E+02	1.2068E+02	1.689	3.0688E+02
7	73	2	.4212	1.9230E-03	4.2066E-03	2.6152E-03	4.2066E-03	20.00	832.960	6.1723E+02	8.7604E+01	1.608	3.6321E+02
8	85	2	.4868	1.7846E-03	4.0354E-03	2.3680E-03	4.0354E-03	20.00	1361.770	7.1055E+02	1.1343E+02	1.704	4.1815E+02
9	93	2	.5745	1.5372E-03	3.4565E-03	1.9742E-03	3.4565E-03	20.00	1820.005	8.9788E+02	1.1476E+02	1.751	5.3051E+02
10	98	2	.6589	1.7302E-03	3.3341E-03	1.8861E-03	3.3341E-03	20.00	2080.406	1.1658E+03	1.1648E+02	1.768	6.3785E+02
11	106	2	.7595	9.9707E-04	2.6932E-03	1.5566E-03	2.6932E-03	20.00	1874.906	1.0453E+03	9.2411E+01	1.730	7.6226E+02
12	118	2	1.1436	5.2541E-04	1.1595E-03	1.1595E-03	1.1595E-03	.40	808.837	4.8174E+01	8.2502E-01	1.000	1.0684E+03
13	120	2	1.5931	5.1243E-04	1.1138E-03	1.1138E-03	1.1138E-03	.40	871.327	4.9245E+01	7.8493E-01	1.000	1.1643E+03
14	122	2	2.0547	4.9956E-04	1.0798E-03	1.0798E-03	1.0798E-03	.40	955.820	5.0943E+01	7.7547E-01	1.000	1.2599E+03
15	124	2	2.5251	4.8293E-04	1.0505E-03	1.0505E-03	1.0505E-03	.40	1032.858	5.2555E+01	7.6924E-01	1.000	1.3556E+03
16	126	2	3.0015	4.6399E-04	1.0287E-03	1.0287E-03	1.0287E-03	.40	1101.911	5.4368E+01	7.7155E-01	1.000	1.4516E+03
17	128	2	3.4837	5.0779E-04	1.0980E-03	1.0980E-03	1.0980E-03	.40	981.994	5.9400E+01	7.3808E-01	1.000	1.5359E+03
18	130	2	3.9705	4.8510E-04	1.0796E-03	1.0796E-03	1.0796E-03	.40	1025.081	6.0733E+01	7.3481E-01	1.000	1.6185E+03
19	132	2	4.4609	4.5898E-04	1.0607E-03	1.0607E-03	1.0607E-03	.40	1068.536	6.1729E+01	7.3282E-01	1.000	1.7014E+03
20	134	2	4.9540	4.2570E-04	1.0412E-03	1.0412E-03	1.0412E-03	.40	1111.660	6.2255E+01	7.3170E-01	1.000	1.7848E+03

.40000000 3.40557831 1238.34002020 5884990.97658741 7

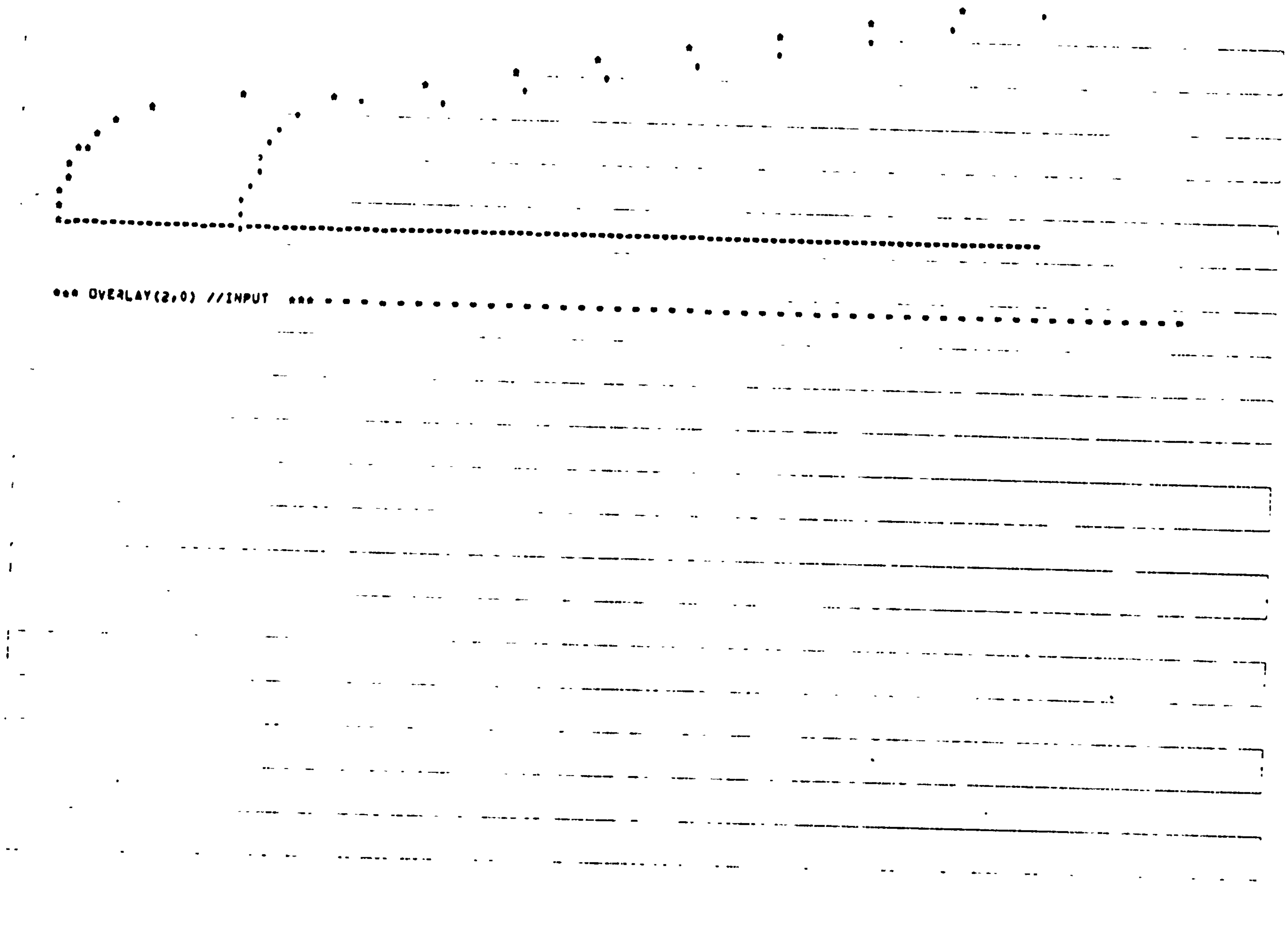
*** OVERLAY(4,0) //THERMB

BODY POINT LOCATIONS AND SURFACE ENERGY BALANCE RESULTS AT
TIME = 17.1500 SEC

* DENOTES ANGLE LIMIT

POINT NUMBER	Z (INCHES)	Z-DOT USED	WALL TEMPERATURE (DEG R)	S-DOT TOTAL (IN/SEC)	S-DOT EROSION (IN/SEC)	PARTICLE ROUGHNESS (MILS)	B-PRIME THERMO-CHEM	CHH	CH (LBM/FT**2-SEC)	CH2
1	1.01056	.00810	2943.22	81.0239E-04	0.	0.	17.5961E-02	79.1100E+00	44.8955E-02	.46712
2 *	1.01280	.00810	2926.58	74.3657E-04	0.	0.	17.5949E-02	72.2830E+00	41.2039E-02	.42876
3	1.05583	.01074	2973.08	10.3135E-03	0.	0.	17.6056E-02	99.4734E+00	57.1164E-02	.55597
4 *	1.05807	.01074	2747.81	31.8588E-04	0.	0.	17.5665E-02	31.1356E+00	17.6828E-02	.17213
5	1.07400	.00924	2942.08	82.8663E-04	0.	0.	17.5995E-02	80.1901E+00	45.9073E-02	.44684
6	1.13066	.00921	2943.23	87.2214E-04	0.	0.	17.6049E-02	83.3375E+00	48.3051E-02	.47018
7 *	1.13290	.00921	2874.76	56.0472E-04	0.	0.	17.5869E-02	54.5565E+00	31.0720E-02	.30245
8	1.14603	.00854	2928.98	77.3291E-04	0.	0.	17.5988E-02	74.5797E+00	42.8414E-02	.41700
9	1.20674	.01050	2921.67	78.4647E-04	0.	0.	17.6052E-02	74.3148E+00	41.0549E-02	.42297
10	1.26171	.01103	2922.76	78.0056E-04	0.	0.	17.6037E-02	74.1555E+00	43.2042E-02	.42053
11	1.33906	.01068	2861.18	59.6588E-04	0.	0.	17.6057E-02	55.1688E+00	31.0390E-02	.32159
12	1.71322	.00692	2457.09	13.1692E-04	0.	0.	17.5649E-02	11.7244E+00	73.1003E-03	.07116
13	2.15595	.00714	2434.53	12.2781E-04	0.	0.	17.5624E-02	10.9128E+00	68.1635E-03	.06635
14	2.61082	.00712	2426.64	11.9805E-04	0.	0.	17.5614E-02	10.6436E+00	66.5154E-03	.06475
15	3.07460	.00711	2420.83	11.7666E-04	0.	0.	17.5606E-02	10.4496E+00	65.3305E-03	.06359
16	3.54458	.00712	2417.57	11.6444E-04	0.	0.	17.5602E-02	10.3375E+00	64.6536E-03	.06294
17	4.02015	.00678	2398.27	10.9672E-04	0.	0.	17.5574E-02	97.3450E-01	60.9035E-03	.05929
18	4.50062	.00677	2394.67	10.8480E-04	0.	0.	17.5569E-02	96.2571E-01	60.2431E-03	.05864
19	4.98475	.00675	2391.98	10.7592E-04	0.	0.	17.5565E-02	95.4411E-01	59.7510E-03	.05816
20	5.47156	.00675	2389.92	10.6925E-04	0.	0.	17.5562E-02	94.8234E-01	59.3817E-03	.05780

TOTAL STAGNATION POINT RECESSION DUE TO EROSION ONLY = 0.0000 INCHES


*** OVERLAY(2,0) //INPUT ***

Sample Problem No. 3

Sample Problem No. 3 is a steady state clear air flight prediction of a 7° ATJ-S graphite sphere cone nosetip with a 0.65-inch nose radius.

This problem repeats the flight environment option, however, this time employing a clear air condition. Again, the sphere-cone input option is used. Also, a short output option is demonstrated.

```
    0  0
C    INPUT DATA
      STEADY STATE
       OF FLIGHT FPA
       ATJ-S GRAPHITE                                             FPA
01
15.2          31.0            1.          .02
-5   1  2  2  2  2  2  2
    .5           22.2           .25         25.2
02
   15.2        150000.      22290.
   19.2        113000.      22290.
   20.2        102300.      22300.
   21.2         92000.      22300.
   22.2         82000.      22250.
   23.2         72500.      22000.
   24.2         62400.      21700.
   25.2         53000.      21100.
   26.2         42600.      20250.
   27.2         35000.      19100.
   28.2         26000.      17700.
   29.2         18500.      16100.
   30.2         10800.      14400.
   31.0          6500.      12800.
   32.2             0.       9700.
03
  25   18        .0625       .25      7.     6000.   1
06
1  117.  530.      0.0       0.7      0.7
1

1    .0004     .001
  460.   .15       .0027     .9
  960.   .31       .0168     .9
 1210.   .45       .0146     .9
 1460.   .38       .0131     .9
 1960.   .43       .0104     .9
 2460.   .465      .0086     .9
 2960.   .49       .0074     .9
 3460.   .505      .0065     .9
 3960.   .515      .0059     .9
 4460.   .52       .0055     .9
 4960.   .525      .0053     .9
 5460.   .525      .0052     .9
*1 9999. .525      .0052     .9
**
   1
   1 1.
 .0100  .00000 4.000003325.8166 .000 5595.743 5595.743 1  C      *  .000
 .0100  .00000 2.000003291.4387 .000 4580.223 4584.223 1  C      *  .000
 .0100  .00000 1.800003284.6345 .000 4401.955 4401.955 1  C      *  .000
 .0100  .00000 1.600003276.4585 .000 4191.066 4191.066 1  C      *  .000
 .0100  .00000 1.400003266.4207 .000 3944.237 3944.237 1  C      *  .000
 .0100  .00000 1.200003253.7492 .000 3651.409 3651.409 1  C      *  .000
 .0100  .00000 1.000003237.1379 .000 3298.330 3298.330 1  C      *  .000
```

.0100	.00000	.800003214.1368	.000	2864.031	2864.031	1	C	*	.000
.0100	.00000	.600003179.3290	.000	2316.016	2316.016	1	C	*	.000
.0100	.00000	.500003153.4915	.000	1983.635	1983.635	1	C	*	.000
.0100	.00000	.400003116.3879	.000	1599.073	1599.073	1	C	*	.000
.0100	.00000	.350003090.1551	.000	1382.302	1382.302	1	C	*	.000
.0100	.00000	.300003054.1960	.000	1144.975	1144.975	1	C	*	.000
.0100	.00000	.250002998.2509	.000	880.830	880.830	1	C	*	.000
.0100	.00000	.220002941.0398	.000	703.014	703.014	1	C	*	.000
.0100	.00000	.200002873.5727	.000	568.912	568.912	1	C	*	.000
.0100	.00000	.190002812.8187	.000	490.765	490.765	1	C	*	.000
.0100	.00000	.180002665.8900	.000	382.537	382.537	1	C	*	.000
.0100	.00000	.17500 935.9883	.000	-166.833	-166.833	1	C	*	.000
.0100	.00000	.17000 871.8156	.000	-206.897	-206.897	1	C	*	.000
1.0000	.00000	4.000003786.7787	.000	5784.608	5784.608	1	C	*	.000
1.0000	.00000	2.000003730.7377	.000	4772.770	4772.770	1	C	*	.000
1.0000	.00000	1.800003919.7092	.000	4589.993	4589.993	1	C	*	.000
1.0000	.00000	1.600003906.6368	.000	4378.359	4378.359	1	C	*	.000
1.0000	.00000	1.400003940.5810	.000	4130.458	4130.458	1	C	*	.000
1.0000	.00000	1.200003870.4112	.000	3636.082	3836.082	1	C	*	.000
1.0000	.00000	1.000003844.1268	.000	3480.735	3400.735	1	C	*	.000
1.0000	.00000	.800003807.4461	.000	3043.019	3043.019	1	C	*	.000
1.0000	.00000	.600003753.8416	.000	2489.554	2489.554	1	C	*	.000
1.0000	.00000	.500003713.9969	.000	2153.044	2153.984	1	C	*	.000
1.0000	.00000	.400003657.2362	.000	1762.725	1762.725	1	C	*	.000
1.0000	.00000	.350003617.3928	.000	1541.949	1541.949	1	C	*	.000
1.0000	.00000	.300003563.1188	.000	1299.272	1249.272	1	C	*	.000
1.0000	.00000	.250003479.3765	.000	1027.102	1027.102	1	C	*	.000
1.0000	.00000	.220003394.5348	.000	881.391	841.391	1	C	*	.000
1.0000	.00000	.200003295.4901	.000	693.292	698.292	1	C	*	.000
1.0000	.00000	.190003207.2959	.000	612.293	612.293	1	C	*	.000
1.0000	.00000	.180002995.6084	.000	486.075	486.075	1	C	*	.000
1.0000	.00000	.175001185.8390	.000	-95.809	-95.809	1	C	*	.000
1.0000	.00000	.170001083.4739	.000	-141.289	-141.289	1	C	*	.000
10.0000	.00000	4.000004427.1046	.000	5921.222	5921.222	1	C	*	.000
10.0000	.00000	2.000004350.7041	.000	4894.925	4894.925	1	C	*	.000
10.0000	.00000	1.800004335.9129	.000	4715.167	4715.167	1	C	*	.000
10.0000	.00000	1.600004319.1419	.000	4501.168	4501.168	1	C	*	.000
10.0000	.00000	1.400004296.4675	.000	4250.411	4250.411	1	C	*	.000
10.0000	.00000	1.200004269.3253	.000	3952.549	3952.549	1	C	*	.000
10.0000	.00000	1.000004234.0984	.000	3592.893	3592.893	1	C	*	.000
10.0000	.00000	.800004185.9962	.000	3149.767	3149.767	1	C	*	.000
10.0000	.00000	.600004114.3455	.000	2589.345	2589.345	1	C	*	.000
10.0000	.00000	.500004062.0876	.000	2245.566	2248.566	1	C	*	.000
10.0000	.00000	.400003988.2193	.000	1853.031	1853.031	1	C	*	.000
10.0000	.00000	.350003936.7399	.000	1629.144	1629.144	1	C	*	.000
10.0000	.00000	.300003867.0729	.000	1382.716	1382.716	1	C	*	.000
10.0000	.00000	.250003760.5196	.000	1105.443	1105.443	1	C	*	.000
10.0000	.00000	.220003653.6239	.000	914.960	914.960	1	C	*	.000
10.0000	.00000	.200003530.0830	.000	766.422	766.422	1	C	*	.000
10.0000	.00000	.190003321. 620	.000	675.551	675.551	1	C	*	.000
10.0000	.00000	.180003167.1427	.000	537.650	537.650	1	C	*	.000
10.0000	.00000	.175001371.4972	.000	-41.901	-41.901	1	C	*	.000
10.0000	.00000	.170001235.0237	.000	-97.718	-97.718	1	C	*	.000
100.0000	.00000	4.000004977.5407	.000	6087.707	6087.707	1	C	*	.000
100.0000	.00000	2.000004867.2644	.000	5040.494	5040.454	1	C	*	.000
100.0000	.00000	1.800004845.6880	.000	4850.690	4850.690	1	C	*	.000
100.0000	.00000	1.600004819.9086	.000	4630.828	4630.828	1	C	*	.000

```
100.0000  .00000 1.100004788.4965 .000 4373.251 4373.251 1  C     *  .000
100.0000  .00000 1.200004749.2472 .000 4067.475 4067.475 1  C     *  .000
100.0000  .00000 1.000004695.5228 .000 3698.719 3698.719 1  C     *  .000
100.0000  .00000  .800004629.7045 .000 3245.377 3245.377 1  C     *  .000
100.0000  .00000  .600004528.7063 .000 2674.121 2674.121 1  C     *  .000
100.0000  .00000  .500004456.0787 .000 2328.097 2328.097 1  C     *  .000
100.0000  .00000  .400004359.9696 .000 1927.815 1927.815 1  C     *  .000
100.0000  .00000  .350004285.5280 .000 1701.816 1701.816 1  C     *  .000
100.0000  .00000  .300004192.7731 .000 1453.371 1453.371 1  C     *  .000
100.0000  .00000  .250004053.3203 .000 1173.626 1173.626 1  C     *  .000
100.0000  .00000  .220003915.9340 .000  980.357  980.357 1  C     *  .000
100.0000  .00000  .200003759.7963 .000  827.635  827.635 1  C     *  .000
100.0000  .00000  .190003624.1510 .000  732.212  732.212 1  C     *  .000
100.0000  .00000  .180003319.3617 .000  581.655  581.655 1  C     *  .000
100.0000  .00000  .175001537.3440 .000   34.688   34.688 1  C     *  .000
100.0000  .00000  .170001438.5134 .000  -38.261  -38.261 1  C     *  .000
500.0000  .00000 4.000005452.7157 .000 6225.105 6225.105 1  C     *  .000
500.0000  .00000 2.000005304.1457 .000 5138.615 5138.615 1  C     *  .000
500.0000  .00000 1.800005279.5576 .000 4941.065 4941.065 1  C     *  .000
500.0000  .00000 1.600005239.0087 .000 4712.312 4712.312 1  C     *  .000
500.0000  .00000 1.400005195.6920 .000 4444.533 4444.533 1  C     *  .000
500.0000  .00000 1.200005141.4257 .000 4127.279 4127.279 1  C     *  .000
500.0000  .00000 1.000005071.4274 .000 3746.079 3746.079 1  C     *  .000
500.0000  .00000  .800004777.1052 .000 3280.424 3280.424 1  C     *  .000
500.0000  .00000  .600004941.2704 .000 2679.451 2679.451 1  C     *  .000
500.0000  .00000  .500004745.6840 .000 2351.065 2351.065 1  C     *  .000
500.0000  .00000  .400004615.5325 .000 1951.367 1951.367 1  C     *  .000
500.0000  .00000  .350004527.9704 .000 1727.121 1727.121 1  C     *  .000
500.0000  .00000  .300004413.0670 .000 1481.500 1481.500 1  C     *  .000
500.0000  .00000  .250004243.9567 .000 1205.311 1205.311 1  C     *  .000
500.0000  .00000  .220004080.7421 .000 1013.670 1013.670 1  C     *  .000
500.0000  .00000  .200003995.3066 .000  860.399  860.399 1  C     *  .000
500.0000  .00000  .190003742.1505 .000  762.851  762.851 1  C     *  .000
500.0000  .00000  .180003391.4579 .000  604.424  604.424 1  C     *  .000
500.0000  .00000  .175001883.5403 .000  110.962  110.962 1  C     *  .000
500.0000  .00000  .170001628.6398 .000   18.164   18.164 1  C     *  .000

=1
C    END OF INPUT DATA
```

STEADY STATE ANALYSIS
OF FLIGHT FPA
ATJ-S GRAPHITE

FPA

---GENERAL PROGRAM CONSTANTS---

```
(TRANSITION CRITERIA CONTROL)             TC =  -5
(ENVIRONMENT CRITERIA CONTROL)           ENV =  1
(CURVE FIT CONTROL)                       CF =  2
(MATERIAL CONSTANT)                       MC =  2
(NO. OF TIME INTERVAL CHANGES)          NTIC =  2
(STEADY STATE FLAG)                      TSS =  2
(OUTPUT PRINT CONTROL)                 IPRNT =  2
(INTERMEDIATE TIME PRINT CONTROL)      LPRNT =  2
```

---TIME INCREMENT INFORMATION---

```
INITIAL TIME (SEC) 15.2000            FINAL TIME (SEC) 31.0000

OUTPUT INTERVAL =  1.0000 SEC FROM INITIAL TIME UNTIL 22.2000 SEC
OUTPUT INTERVAL =   .5000 SEC FROM  22.2000 SEC UNTIL 25.2000 SEC
OUTPUT INTERVAL =   .2500 SEC FROM  25.2000 SEC UNTIL FINAL TIME

TIME STEP STABILITY CRITERIA IN EFFECT
MINIMUM TIME STEP =2.0000E-02SECONDS
CTF =  1.300          STRD = 75.000
```

---FLIGHT ENVIRONMENT---

TIME (SEC)	ALTITUDE (FT)	VELOCITY (FPS)
15.200	150000.0	22290.0
19.200	113000.0	22290.0
20.200	102300.0	22300.0
21.200	92000.0	22300.0
22.200	82000.0	22250.0
23.200	72500.0	22000.0
24.200	62400.0	21700.0
25.200	53000.0	21100.0
26.200	42600.0	20250.0
27.200	35000.0	19100.0
28.200	26000.0	17700.0
29.200	18500.0	16100.0
30.200	10800.0	14400.0
31.000	6500.0	12800.0
32.200	0.0	9700.0

BUILT-IN ATMOSPHERIC TABLE, 1962 U.S. STANDARD.

I	ALTITUDE(FT)	DENSITY(LBM/FT3)	PRESSURE(ATM)
1	0.	7.647400E-02	1.000000E+00
2	3.000000E+03	6.998400E-02	8.962600E-01
3	6.000000E+03	6.392500E-02	8.014300E-01
4	1.000000E+04	5.648300E-02	6.878300E-01
5	2.000000E+04	4.077300E-02	4.599100E-01
6	3.000000E+04	2.865700E-02	2.975400E-01
7	4.000000E+04	1.889500E-02	1.857700E-01
8	5.000000E+04	1.170900E-02	1.151200E-01
9	6.000000E+04	7.258900E-03	7.136600E-02
10	7.000000E+04	4.478700E-03	4.429000E-02
11	8.000000E+04	2.757600E-03	2.764900E-02
12	9.000000E+04	1.710000E-03	1.737900E-02
13	1.000000E+05	1.067600E-03	1.099700E-02
14	1.100000E+05	6.647000E-04	7.011200E-03
15	1.200000E+05	4.150600E-04	4.537100E-03
16	1.300000E+05	2.635300E-04	2.981500E-03
17	1.400000E+05	1.699400E-04	1.987600E-03
18	1.500000E+05	1.111900E-04	1.342900E-03
19	1.600000E+05	7.471300E-05	9.176400E-04
20	1.700000E+05	5.115900E-05	6.283400E-04
21	1.800000E+05	3.557800E-05	4.292400E-04
22	1.900000E+05	2.466300E-05	2.908500E-04
23	2.000000E+05	1.695700E-05	1.953700E-04
24	2.100000E+05	1.174800E-05	1.296400E-04
25	2.200000E+05	8.035600E-06	8.431900E-05
26	2.300000E+05	5.399800E-06	5.362700E-05
27	2.400000E+05	3.535300E-06	3.326900E-05
28	2.500000E+05	2.243000E-06	2.007400E-05
29	2.600000E+05	1.409000E-06	1.174000E-05
30	2.700000E+05	8.172000E-07	6.699600E-06
31	2.800000E+05	4.661000E-07	3.821100E-06
32	3.000000E+05	1.488000E-07	1.248900E-06
33	3.200000E+05	4.774000E-08	4.803400E-07
34	3.400000E+05	1.654000E-08	1.717000E-07
35	3.600000E+05	6.385000E-09	7.513300E-08
36	3.800000E+05	2.579000E-09	3.732200E-08
37	4.000000E+05	1.164000E-09	2.107100E-08
38	4.200000E+05	5.751000E-10	1.359700E-08
39	4.400000E+05	3.301000E-10	9.631500E-09
40	4.600000E+05	2.088000E-10	7.248500E-09

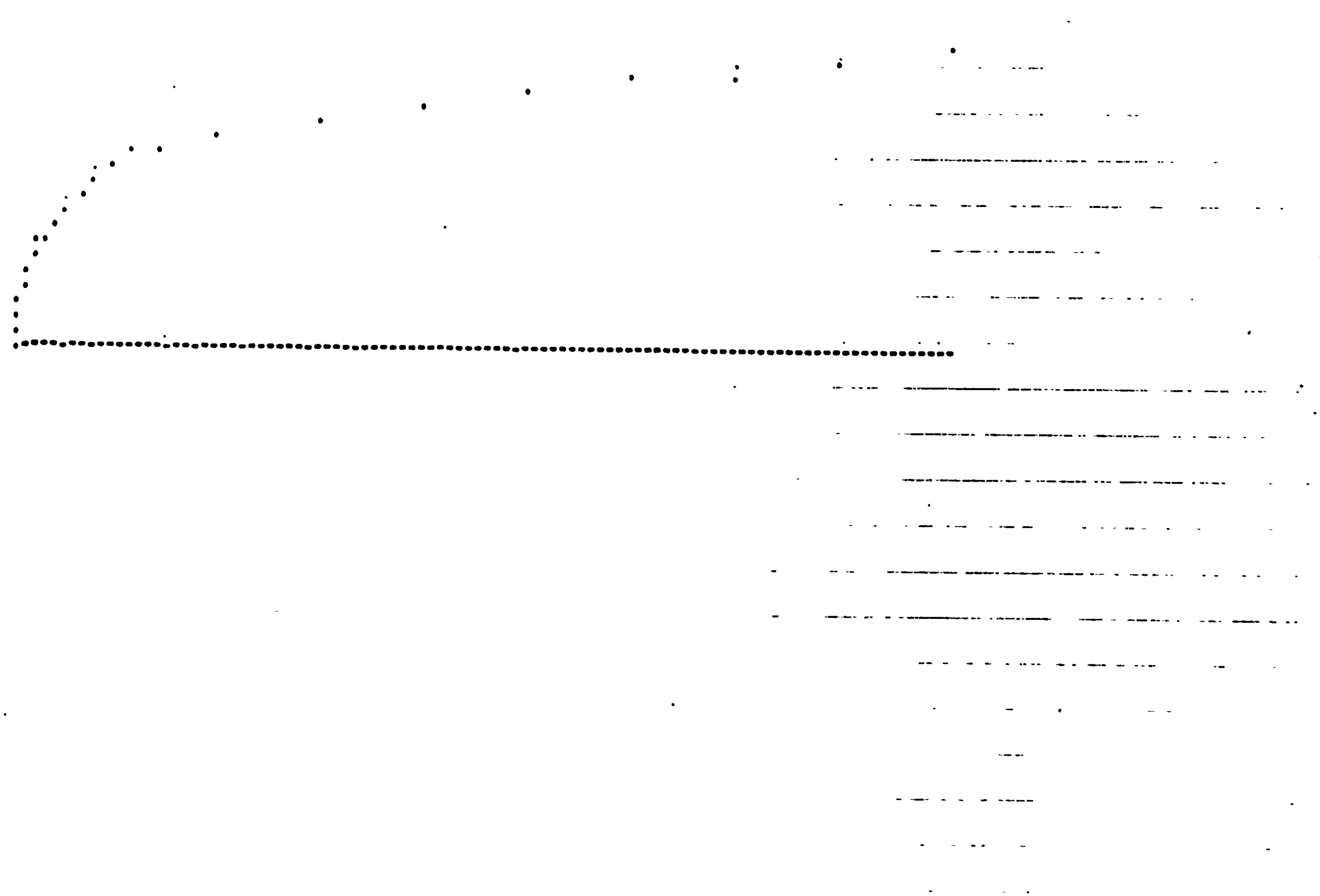
INITIAL GEOMETRY---

SPHERE CONE OPTION - GENERATED SHAPE

```
INITIAL NOSE RADIUS =    .7500 INCHES
CONE ANGLE          =   7.0000 DEGREES
MAXIMUM *Z*         =   3.0000 INCHES
```

I	ZOUT	ROUT	SLOP
1	0.00000	0.00000	90.00000
			88.32500
2	.00128	.04379	86.65000
			84.97210
3	.00513	.08758	83.29427
			81.60329
4	.01159	.13137	79.91231
			78.20336
5	.02074	.17516	76.49441
			74.76058
6	.03267	.21894	73.02674
			71.26022
7	.04752	.26273	69.49370
			67.68539
8	.06550	.30652	65.87709
			64.01607
9	.08684	.35031	62.15505
			60.22773
10	.11189	.39410	58.30041
			56.28929
11	.14110	.43789	54.27816
			52.15971
12	.17512	.48168	50.04126
			47.78222
13	.21485	.52547	45.52317
			43.07327
14	.26169	.56925	40.62336
			37.89905
15	.31794	.61304	35.17554
			32.01929
16	.38796	.65683	28.86305
			24.88501
17	.48236	.70062	20.90697
			16.21336
18	.65860	.74441	11.51975
			9.25988
19	.99308	.78548	7.00000
			7.00000
20	1.32757	.82655	7.00000
			7.00000
21	1.66206	.86762	7.00000
			7.00000
22	1.99654	.90869	7.00000
			7.00000
23	2.33103	.94976	7.00000
			7.00000
24	2.66551	.99083	7.00000
			7.00000
25	3.00000	1.03190	6.99999

---INITIAL SHAPE PLOT---



---MATERIAL PROPERTIES---

******* M A T E R I A L   N U M B E R   1 *******

---SURFACE ROUGHNESS---

ROUGHNESS HEIGHT FOR LAMINAR HEATING AND TRANSITION   K-LAN = .00040 (INCH)
ROUGHNESS HEIGHT FOR TURBULENT HEATING   K-TURB = .00100 (INCH)

FLAG FOR TYPE OF ROUGH TURBULENT HEATING   JROUGH = 1

---THERMAL PROPERTIES---

RHO = 117.00
TFO = 530.00
HFO = 0.00
TBRPL = .70
TBRPT = .70

TEMPERATURE (DEG R)	SPECIFIC HEAT (BTU/LB-DEG)	CONDUCTIVITY (BTU/FT-SEC-DEG)	SENSIBLE ENTHALPY (BTU/LB)	EMISSIVITY
460.00	.1500	.0027000	-16.10	.9000
960.00	.3100	.0168000	98.90	.9000
1210.00	.3500	.0146000	181.40	.9000
1460.00	.3800	.0131000	272.65	.9000
1960.00	.4300	.0104000	475.15	.9000
2460.00	.4650	.0086000	698.90	.9000
2960.00	.4900	.0074000	937.65	.9000
3460.00	.5050	.0065000	1186.40	.9000
3960.00	.5150	.0059000	1441.40	.9000
4460.00	.5200	.0055000	1700.15	.9000
4960.00	.5250	.0053000	1961.40	.9000
5460.00	.5250	.0052000	2223.90	.9000
9999.00	.5250	.0052000	4606.87	.9000

---SURFACE EQUILIBRIUM DATA---

MAT = 1
NBPF = 0
CMH = 1.00000

M-DOT-GAS/CM = 0.0000 PRESSURE = .0100 ATM

TEMP	BPRIM	HCH	TSEN	TCHEM	SPECIE
1569.2681	.1700	316.9036	-361.6146	476.9627	C
1684.7749	.1750	363.6855	-300.2994	416.4968	C
4798.6020	.1800	1877.0695	688.5666	-474.6361	C
5063.0737	.1900	2015.5137	883.3770	-668.2710	C
5172.4309	.2000	2072.9262	1024.0416	-814.2647	C
5293.8716	.2200	2136.6826	1265.4252	-1073.7486	C
5394.8516	.2500	2190.7471	1585.4940	-1434.1807	C
5497.5528	.3000	2243.6152	2060.9550	-2006.1569	C
5562.2792	.3500	2277.5966	2488.1436	-2561.8351	C
5604.4982	.4000	2302.3866	2878.3314	-3108.7093	C
5674.2847	.5000	2337.4495	3570.5436	-4187.0859	C
5722.7922	.6000	2361.8659	4168.8288	-5253.0065	C
5785.4462	.8000	2394.7593	5155.2558	-7363.6530	C
5826.8482	1.0000	2416.4953	5936.9940	-9457.4927	C
5856.7486	1.2000	2432.1930	6572.5362	-11540.9480	C
5879.5573	1.4000	2444.1676	7099.6266	-13617.2693	C
5897.6253	1.6000	2453.6533	7543.9188	-15638.3436	C
5912.3421	1.8000	2461.3796	7923.5190	-17755.3699	C
5924.5897	2.0000	2467.8096	8251.6014	-19819.1851	C
5986.4699	4.0000	2500.2967	10072.3374	-40360.5003	C

M-DOT-GAS/CM = 0.0000 PRESSURE = 1.0000 ATM

TEMP	BPRIM	HCH	TSEN	TCHEM	SPECIE
1950.2530	.1700	971.2025	-254.3202	377.6591	C
2134.5102	.1750	553.2433	-172.4562	299.4536	C
5397.4951	.1800	2191.0449	874.9350	-638.0280	C
5773.1326	.1900	2388.2946	1102.1274	-857.7556	C
5931.8822	.2000	2471.6381	1256.9256	-1013.9831	C
6110.1626	.2200	2565.2354	1514.5038	-1283.3429	C
6262.8777	.2500	2645.4108	1848.7836	-1649.6268	C
6413.6138	.3000	2724.5473	2338.6896	-2222.9323	C
6511.3070	.3500	2775.8362	2775.5082	-2775.3934	C
6583.0252	.4000	2813.4882	3172.9050	-3316.6717	C
6685.1944	.5000	2867.1271	3875.5512	-4379.7633	C
6756.9142	.6000	2904.7799	4481.1972	-5427.0476	C
6854.3942	.8000	2955.9570	5477.4342	-7494.6160	C
6919.4282	1.0000	2990.0998	6265.3230	-9540.5462	C
6966.7402	1.2000	3014.9386	6904.9476	-11572.9584	C
7003.0458	1.4000	3033.9990	7434.8244	-13595.9799	C
7031.9462	1.6000	3049.1718	7881.0462	-15612.0453	C
7055.5845	1.8000	3061.5819	8251.9874	-17622.7173	C
7075.3279	2.0000	3071.9471	8590.9860	-19629.0637	C
7176.2017	4.0000	3124.9059	10412.2944	-39561.8485	C

M-DOT-GAS/CM = 0.0000 PRESSURE = 10.0000 ATM

TEMP	BPRIM	HCH	TSEN	TCHEM	SPECIE
2223.0427	.1700	592.8616	-175.8924	306.5806	C
2468.5330	.1750	702.9745	-75.4218	211.6412	C
5701.2169	.1800	2350.5389	967.7700	-718.8716	C
6158.0916	.1900	2590.3981	1215.9918	-954.8546	C
6350.1494	.2000	2693.3284	1379.5596	-1116.8058	C
6576.5230	.2200	2810.0746	1646.9280	-1391.0358	C
6768.9353	.2500	2911.0910	1989.7974	-1759.4740	C
6960.7312	.3000	3011.7839	2488.8888	-2332.0203	C
7086.1318	.3500	3077.6192	2932.4592	-2881.6532	C
7178.7929	.4000	3126.2663	3335.4558	-3419.1316	C
7311.7577	.5000	3196.0728	4047.0188	-4473.0918	C
7405.8219	.6000	3245.4565	4660.8210	-5510.0397	C
7534.7032	.8000	3313.1192	5669.5806	-7554.7498	C
7621.3771	1.0000	3359.6230	6467.2074	-9575.7918	C
7684.7855	1.2000	3391.9124	7114.5882	-11581.7991	C
7733.6415	1.4000	3417.5618	7650.7398	-13577.1890	C
7772.6554	1.6000	3438.0441	8102.1024	-15564.5957	C
7804.6432	1.8000	3454.8377	8487.3006	-17545.7338	C
7831.4114	2.0000	3468.8910	8819.8650	-19521.8131	C
7968.7883	4.0000	3541.0138	10658.1996	-39126.9426	C

M-DOT-GAS/CM = 0.0000 PRESSURE = 100.0000 ATM

TEMP	BPRIM	HCH	TSEN	TCHEM	SPECIE
2589.3241	.1700	760.6523	-68.8698	209.8886	C
2934.6192	.1750	925.5307	62.4384	88.6027	C
5[illegible]35.8505	.1800	2489.4715	1046.9790	-787.3303	C
6523.4898	.1900	2782.2321	1317.9816	1039.7740	C
6767.6333	.2000	2910.4075	1489.7430	-1205.6101	C
7048.6812	.2200	3057.[illegible]576	1764.6426	-1480.1133	C
7295.9765	.2500	3187.7877	2112.5268	-1843.7116	C
7546.9916	.3000	3319.5706	2616.0678	-2405.0170	C
7713.9504	.3500	3407.2240	3063.2688	-2942.8845	C
7838.9453	.4000	3472.8463	3470.0670	-3468.9553	C
8020.9417	.5000	3568.3944	4190.5746	-4501.6647	C
8151.6713	.6000	3637.0275	4813.4178	-5519.2520	C
8333.4681	.8000	3732.4708	5841.6786	-7529.0449	C
8457.3410	1.0000	3797.5040	6657.6942	-9517.8844	C
8548.6450	1.2000	3845.4386	7321.4550	-11492.6747	C
8619.2937	1.4000	3882.5292	7871.8518	-13456.9035	C
8675.8355	1.6000	3912.2136	8335.0998	-15412.7332	C
8722.2384	1.8000	3936.5752	8731.2420	-17361.6423	C
8761.0759	2.0000	3956.7649	9072.8892	-19304.7779	C
8959.5733	4.0000	4061.1760	10957.8726	-38544.6592	C

M-DOT-GAS/CM = 0.0000 PRESSURE = 500.0000 ATM

TEMP	BPRIM	HCH	TSEN	TCHEM	SPECIE
2931.5516	.1700	924.0659	32.6952	118.8378	C
3390.3725	.1750	1151.7603	199.7316	-33.1266	C
6105.5242	.1800	2562.8002	1087.9632	-822.4925	C
6735.8709	.1900	2893.7322	1373.1318	-1084.2177	C
7017.0959	.2000	3041.3753	1548.7182	-1250.1868	C
734[illegible].3358	.2200	3213.7013	1824.4060	-1519.0050	C
7639.1221	.2500	3367.9391	2169.5598	-1869.9650	C
7943.5217	.3000	3527.7489	2666.7000	-2408.3853	C
8150.3629	.3500	3636.3405	3108.8178	-2924.1848	C
8307.7585	.4000	3719.0782	3512.4606	-3429.8135	C
8542.2323	.5000	3642.0719	4231.9170	-4426.8395	C
8714.3299	.6000	3932.4232	4859.0118	-5414.9650	C
8958.9334	.6300	4060.8400	5904.7632	-7379.9017	C
9[illegible].5693	1.0000	4149.8989	6742.9752	-9335.0575	C
9294.5653	1.2000	4216.0473	7429.1022	-11284.7681	C
9352.2463	1.4000	4267.3293	8000.1598	-13226.1215	C
9430.3237	1.6000	4308.3199	8482.1616	-15160.3083	C
9494.2037	1.8000	4341.8569	8893.9530	-17087.7259	C
9547.4626	2.0000	4369.8179	9249.5070	-19008.8852	C
9814.8703	4.0000	4510.2069	11205.2970	-37985.6575	C

```
*** OVERLAY(3,0) //ENVIRT ***
```

*** OVERLAY(3,1) //VORT1 *** *

SHOULDER POINT = 19   SONIC POINT = 15

*** STAGNATION POINT ENVIRONMENT HISTORY FOR THE INITIAL BODY SHAPE ***

	* *STAGNATION POINT QUANTITIES* *			* * *FREESTREAM QUANTITIES* * *		
TIME (SEC)	PRESSURE (ATM)	ENTHALPY (BTU/LBM)	HEAT TRANS.COEFF. (LBM/FT2-SEC)	VELOCITY (FT/SEC)	DENSITY (LBM/FT3)	PRESSURE (ATM)
15.2000	7.853E-01	1.005E+04	1.595E-01	2.229E+04	1.112E-04	1.343E-03
19.2000	4.065E+00	1.004E+04	3.657E-01	2.229E+04	5.771E-04	6.153E-03
20.2000	6.743E+00	1.004E+04	4.721E-01	2.230E+04	4.574E-04	9.915E-03
21.2000	1.095E+01	1.004E+04	6.028E-01	2.230E+04	1.534E-03	1.586E-02
22.2000	1.754E+01	9.995E+03	7.646E-01	2.225E+04	2.506E-03	2.520E-02
23.2000	2.712E+01	9.782E+03	9.539E-01	2.200E+04	3.967E-03	3.937E-02
24.2000	4.295E+01	9.510E+03	1.205E+00	2.170E+04	6.465E-03	6.365E-02
25.2000	6.362E+01	9.006E+03	1.474E+00	2.110E+04	1.014E-02	9.973E-02
26.2000	9.620E+01	8.284E+03	1.825E+00	2.025E+04	1.668E-02	1.640E-01
27.2000	1.191E+02	7.379E+03	2.044E+00	1.910E+04	2.327E-02	2.351E-01
28.2000	1.448E+02	6.372E+03	2.263E+00	1.770E+04	3.300E-02	3.542E-01
[illegible]	1.552E+02	5.294E+03	2.342E+00	1.610E+04	4.282E-02	4.885E-01
[illegible]	1.594E+02	4.270E+03	2.340E+00	1.440E+04	5.503E-02	6.660E-01
[illegible]	1.439E+02	3.399E+03	2.218E+00	1.280E+04	6.294E-02	7.863E-01
[illegible]	9.975E+01	2.004E+03	1.771E+00	9.700E+03	7.687E-02	1.000E+00

*** OVERLAY([illegible]) //VIRT *** *

*** OVERLAY(3,2) //VORT15 *** *

NEW CURVE FIT DONE TO BODY POINTS
9CURVES FIT TO,101 POINTS

CURVE	A	B	C	AUC(I+1)
1	20.00048E+04	16.10484E+04	-13.27894E-15	11.18031E-03
2	-13.60030E+04	16.59046E+04	-49.53609E+00	22.27038E-03
3	-12.68054E+04	[illegible]	-44.97456E+00	33.59023E-03
4	-86.82370E+04	[illegible]	-88.15341E+01	45.78365E-03
5	-36.49999E+04	17.32265E+04	17.33229E+01	59.30787E-03
6	13.19605E+05	-26.59892E+03	60.98934E+02	71.89939E-03
7	-31.50999E+05	61.62743E+04	-17.01216E+03	95.88363E-03
8	-20.03704E+03	[illegible]	11.77287E+03	28.70608E-02
9	-19.45510E+04	11.65865E+04	-25.96991E+02	29.28021E-02

*** OVERLAY(3,3) //VORT2 *** *

TIME=, 15.20 SEC

O U T P U T

* VORT CALLED AT FIRST TIME STEP *

TABLE-1 SUMMARY INFORMATION

ITERATION NO. ITR	ITERATION NO. ITS	TIMEP (SEC)	ALTITUDE ALT (FT)	FREESTREAM MACH-NO. M-INF	STAGNATION PT. PRESSURE P2 (ATM)	STAGNATION PT. ENTHALPY HO (BTU/LBM)
1	0	15.2000	150000	20.782	.7853	10045.7

STAG. PT. RECESSION SPREC (INCH)	CURRENT NOSE RADIUS RN (INCH)	EFFECTIVE NOSE RADIUS R-EFF (INCH)	STAGNATION PT. HEAT TRANS. COEF. SPHTC (LBM/FT**2-SEC)	TRANSITION STREAM LENGTH S-TRAN (INCH)	SONIC PT. AXIAL LENGTH X-STAR (INCH)	SONIC PT. RADIAL LENGTH Y-STAR (INCH)
0.0000	.7491	.5925	.1717	0.0000	.1628	.4657

TABLE-2 SUMMARY DISTRIBUTION TABLE

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, LAM = TRANSITION FLAG.

J	I	LAM	STREAM LENGTH S (INCH)	AXIAL LENGTH X (INCH)	RADIAL LENGTH Y (INCH)	BODY ANGLE (DEG)	PRESSURE RATIO PE/PT2	EDGE MACH ME	ROUGHNESS HEIGHT K MIL	LAMINAR CHO CHO-LAM (LBM/FT2-SEC)	TURBULENT CHO CHO-TURB	HEATING AUG. PARAMETER FKR	MOMENTUM THICKNESS THETA (MIL)	MOMENTUM THICKNESS REYNOLDS NO. RE-THET/
	1	1	0.0000	0.0000	0.0000	90.00	1.000000	0.0000	.40000	.17166	.17166	1.0000	2.345	0.00
1	6	1	.0438	.0013	.0438	86.65	.995972	.0960	.40000	.17185	.17129	1.0000	2.342	1.92
2	11	1	.0878	.0051	.0876	83.29	.984061	.1936	.40000	.17108	.17085	1.0000	2.351	3.88
3	16	1	.1320	.0116	.1314	79.91	.964310	.2935	.40000	.16936	.16948	1.0000	2.371	5.88
4	21	1	.1768	.0207	.1752	76.49	.936848	.3953	.40000	.16628	.16678	1.0000	2.409	7.91
5	26	1	.2221	.0327	.2189	73.03	.901866	.4988	.40000	.16192	.16323	1.0000	2.466	9.95
6	31	1	.2684	.0475	.2627	69.49	.859629	.6047	.40000	.15650	.15879	1.0000	2.541	12.02
7	36	1	.3157	.0655	.3065	65.88	.810492	.7138	.40000	.15007	.15338	1.0000	2.637	14.09
8	41	1	.3644	.0868	.3503	62.16	.754917	.8270	.40000	.14265	.14690	1.0000	2.759	16.16
9	46	1	.4149	.1119	.3941	58.30	.693503	.9454	.40000	.13417	.13915	1.0000	2.918	18.23
10	51	1	.4675	.1411	.4379	54.28	.626769	1.0673	.40000	.12417	.12998	1.0000	3.120	20.27
11	56	1	.5230	.1751	.4817	50.04	.550047	1.1922	.40000	.11198	.11825	1.0000	3.429	22.25
12	61	1	.5821	.2148	.5255	45.52	.474715	1.3220	.40000	.09969	.10604	1.0000	3.815	24.13
13	66	1	.6462	.2617	.5693	40.62	.397807	1.4628	.40000	.08686	.09281	1.0000	4.335	25.92
14	71	1	.7175	.3179	.6130	35.19	.319108	1.6211	.40000	.07317	.07852	1.0000	5.088	27.61
15	76	1	.8001	.3880	.6568	28.86	.234328	1.8250	.40000	.05820	.06184	1.0000	6.360	29.19
16	78	1	.9041	.4824	.7006	20.91	.128836	2.1359	.40000	.03622	.03842	1.0000	10.013	30.36
17	80	1	1.0857	.6586	.7444	11.52	.075757	2.4714	.40000	.02227	.02446	1.0000	15.051	31.71
18	83	1	1.4227	.9931	.7855	7.00	.047713	2.6210	.40000	.01324	.01604	1.0000	23.484	34.12
19	86	1	1.7597	1.3276	.8265	7.00	.041809	2.7025	.40000	.01161	.01408	1.0000	26.517	35.71
20	89	1	2.0967	1.6621	.8676	7.00	.037264	2.7761	.40000	.01039	.01261	1.0000	29.338	36.94
21														

TIME=, 15.20 SEC FPA PAGE 12

	92	1	2.4337	1.9945	.9087	7.00	.033828	2.8410	.40000	.00948	.01152	1.0000	31.842	37.92
22	95	1	2.7707	2.3310	.9498	7.00	.031254	2.8984	.40000	.00879	.01071	1.0000	33.986	38.72
23	98	1	3.1077	2.6655	.9908	7.00	.029291	2.9471	.40000	.00828	.01010	1.0000	35.819	39.41
24	101	1	3.4447	3.0000	1.0319	7.00	.027692	3.0215	.40000	.00789	.00961	1.0000	37.083	40.02
25														

*** OVERLAY(4,0) //THERMS *** -

BODY POINT LOCATIONS AND SURFACE ENERGY BALANCE RESULTS AT
TIME = 16.2000 SEC

* DENOTES ANGLE LIMIT

POINT NUMBER	Z (INCHES)	Z-DOT USED	WALL TEMPERATURE (DEG R)	S-DOT TOTAL (IN/SEC)	S-DOT EROSION (IN/SEC)	PARTICLE ROUGHNESS (MILS)	B-PRIME THERMO-CHEM	CHH	CH (LBM/FT**2-SEC)	CHZ
1	.00547	.00547	6517.52	54.6997E-04	0.	0.	38.9213E-02	13.5898E+02	13.7026E-02	.17166
2	.00677	.00549	6517.21	54.8049E-04	0.	0.	38.9613E-02	13.6005E+02	13.7148E-02	.17185
3	.01061	.00548	6513.47	54.4590E-04	0.	0.	38.8717E-02	13.5412E+02	13.6597E-02	.17108
4	.01704	.00545	6506.19	53.6607E-04	0.	0.	38.6503E-02	13.4114E+02	13.5366E-02	.16936
5	.02411	.00537	6494.38	52.2194E-04	0.	0.	38.2301E-02	13.1837E+02	13.3178E-02	.16628
6	.03792	.00525	6477.90	50.1817E-04	0.	0.	37.6141E-02	12.8627E+02	13.0077E-02	.16192
7	.05261	.00509	6457.64	47.6580E-04	0.	0.	36.8270E-02	12.4600E+02	12.6175E-02	.15650
8	.07040	.00490	6431.29	44.7242E-04	0.	0.	35.8642E-02	11.9872E+02	12.1597E-02	.15007
9	.09152	.00468	6396.56	41.3824E-04	0.	0.	34.7063E-02	11.4392E+02	11.6255E-02	.14265
10	.11631	.00442	6356.17	37.6251E-04	0.	0.	33.3127E-02	10.8109E+02	11.0121E-02	.13417
11	.14521	.00410	6303.18	33.3005E-04	0.	0.	31.5734E-02	10.0689E+02	10.2833E-02	.12417
12	.17880	.00368	6229.69	28.2189E-04	0.	0.	29.3392E-02	91.5520E+01	93.7772E-03	.11194
13	.21813	.00328	6136.72	23.4293E-04	0.	0.	27.0178E-02	82.2763E+01	84.5500E-03	.09969
14	.26457	.00288	6021.68	18.7595E-04	0.	0.	24.4909E-02	72.4002E+01	74.6829E-03	.08686
15	.32043	.00249	5859.44	14.3438E-04	0.	0.	21.9161E-02	61.5803E+01	63.8127E-03	.07317
16	.39011	.00215	5608.96	10.3762E-04	0.	0.	19.6808E-02	49.3086E+01	51.4045E-03	.05820
17	.48403	.00167	5044.92	53.6127E-05	0.	0.	17.9917E-02	30.6738E+01	32.3059E-03	.03622
18	.66043	.00183	4485.45	36.5156E-05	0.	0.	17.9131E-02	18.7095E+01	19.8753E-03	.02227
19	.99486	.00177	3953.25	21.6148E-05	0.	0.	17.8373E-02	11.0379E+01	11.8148E-03	.01324
20	1.32412	.00155	3828.59	18.9456E-05	0.	0.	17.8200E-02	96.6019E+00	10.3658E-03	.01161
21	1.66345	.00139	3725.88	16.9441E-05	0.	0.	17.8058E-02	86.2779E+00	92.7817E-04	.01039
22	1.99781	.00127	3643.12	15.4444E-05	0.	0.	17.7943E-02	78.5448E+00	84.6281E-04	.00948
23	2.33220	.00117	3575.58	14.3115E-05	0.	0.	17.7851E-02	72.7046E+00	78.4572E-04	.00879
24	2.66662	.00110	3519.89	13.4244E-05	0.	0.	17.7774E-02	68.1334E+00	73.6258E-04	.00824
25	3.00105	.00105	3482.16	12.8513E-05	0.	0.	17.7725E-02	65.1623E+00	70.5026E-04	.00789

TOTAL STAGNATION POINT RECESSION DUE TO EROSION ONLY = 0.0000 INCHES

*** OVERLAY(3,0) //ENVIRI *** -

*** OVERLAY(3,1) //VORTI *** -

SHOULDER POINT = 19 SONIC POINT = 15

*** OVERLAY(3,2) //VORTIS *** -

NEW CURVE FIT DONE TO BODY POINTS
9CURVES FIT TO,101 POINTS

CURVE	A	B	C	AUC(I+1)
1	-18,24252E+03	16,16077E+04	-25,12895E-15	11,32362E-03
2	-13,91394E+04	16,43457E+04	-15,50174E+00	22,61518E-03
3	-29,47353E+04	17,16095E+04	-97,63814E+00	34,51428E-03
4	35,73357E+04	12,62528E+04	68,50883E+01	46,09605E-03
5	-16,30495E+05	30,95152E+04	-35,38747E+02	59,45682E-03
6	25,42545E+05	-18,67143E+04	11,21343E+03	71,77143E-03
7	-37,32490E+05	71,40202E+04	-21,11015E+03	94,05743E-03
8	-20,32499E+03	15,70690E+03	11,73063E+03	28,68076E-02
9	-20,15232E+04	11,62291E+04	-24,51525E+02	29,25438E-02

*** OVERLAY(3,3) //VORTS *** -

TIME=, 30.95 SEC FPA PAGE184

****
* VORT CALLED AT SPECIFIED OUTPUT TIME *
****

TABLE-1 SUMMARY INFORMATION

ITERATION NO. ITS	ITERATION NO. ITS	TIMEP (SEC)	ALTITUDE ALT (FT)	FREESTREAM MACH-NO. M-INF	STAGNATION PT. PRESSURE PT2 (ATM)	STAGNATION PT. ENTHALPY HO (BTU/LBM)
63	0	30.9500	6769	11.838	144.9132	3449.0

STAG. PT. RECESSION SPREC (INCH)	CURRENT NOSE RADIUS RN (INCH)	EFFECTIVE NOSE RADIUS R-EFF (INCH)	STAGNATION PT. HEAT TRANS. COEF. SPHTC (LBM/FT**2-SEC)	TRANSITION STREAM LENGTH S-TRAN (INCH)	SONIC PT. AXIAL LENGTH X-STAR (INCH)	SONIC PT. RADIAL LENGTH Y-STAR (INCH)
2.1171	.0082	.0073	21.3578	.0039	2.1189	.0051

TABLE-2 SUMMARY DISTRIBUTION TABLE

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, LAM = TRANSITION FLAG

J	I	LAM	STREAM LENGTH S (INCH)	AXIAL LENGTH X (INCH)	RADIAL LENGTH Y (INCH)	BODY ANGLE (DEG)	PRESSURE RATIO PE/PT2	EDGE MACH ME	ROUGHNESS HEIGHT K MIL	LAMINAR CHO CHO-LAM (LBM/FT2-SEC)	TURBULENT CHO CHO-TURB	HEATING AUG. PARAMETER FKR	MOMENTUM THICKNESS THETA (MIL)	MOMENTUM THICKNESS REYNOLDS NO. RE-THETA
	1	1	0.0000	2.1171	0.0000	90.00	1.000000	0.0000	.80000	31.87373	31.87373	1.4924	.013	0.00
1	22	-1	.0851	2.1912	.0438	27.64	.219481	4.2465	1.00000	2.97245	11.47798	1.7451	.130	1013.35
2	30	-1	.1509	2.2363	.0876	44.16	.485100	3.7422	1.00000	5.34930	22.40519	1.9257	.204	2517.82
3	32	-1	.2136	2.2811	.1314	44.33	.491121	2.7065	1.00000	3.74807	15.51117	1.8263	.653	3903.68
4	34	-1	.2667	2.3112	.1752	55.50	.680866	2.3191	1.00000	4.14363	18.61513	1.8769	.752	4620.02
5	36	-1	.3265	2.3520	.2189	47.09	.538859	2.4374	1.00000	2.89504	14.07972	1.8100	1.022	5454.40
6	42	-1	.3728	2.3670	.2627	70.98	.894380	1.5612	1.00000	4.12344	15.39729	1.8414	1.363	5932.83
7	47	-1	.4281	2.4008	.3065	52.35	.628909	1.8374	1.00000	2.77752	11.78593	1.7746	1.051	6473.66
8	50	-1	.4761	2.4205	.3503	65.86	.833589	1.8119	1.00000	3.16270	15.99280	1.8578	1.380	6938.85
9	54	-1	.5333	2.4572	.3941	49.26	.575255	2.1488	1.00000	2.26888	12.13970	1.7912	1.670	7634.45
10	56	-1	.5918	2.4959	.4379	48.50	.563202	1.5880	1.00000	1.99320	8.32299	1.7088	2.870	8089.85
11	62	-1	.6400	2.5161	.4817	65.24	.825554	1.2720	1.00000	2.69175	10.09887	1.7552	2.727	8303.09
12	64	-1	.6931	2.5462	.5255	50.29	.593912	1.6671	1.00000	2.06807	9.21963	1.7381	2.709	8649.95
13	66	-1	.7501	2.5915	.5693	49.03	.485896	1.9155	1.00000	1.62111	8.40352	1.7121	2.801	9045.60
14	68	-1	.8139	2.6292	.6130	49.26	.576303	1.8201	1.00000	1.73330	9.57920	1.7483	2.664	9431.55
15	70	-1	.8792	2.6777	.6568	40.96	.432720	1.7165	1.00000	1.41138	6.31112	1.6508	4.027	9800.33
16	72	-1	.9477	2.7303	.7006	39.31	.404501	1.7801	1.00000	1.23593	6.16878	1.6394	4.188	10065.53
17	74	-1	1.0175	2.7847	.7444	38.84	.396557	1.9104	1.00000	1.11694	6.33429	1.6489	3.947	10356.91
18	76	-1	1.0820	2.8345	.7855	39.52	.408088	2.0201	1.00000	1.07193	6.92450	1.6728	3.614	10664.80
19	78	-1	1.1518	2.8908	.8265	35.92	.347627	2.2340	1.00000	.89180	6.32436	1.6500	3.715	11027.31
20	80	-1	1.2221	2.9479	.8676	34.03	.316831	2.3567	1.00000	.79838	5.93503	1.6343	3.824	11369.84
21	82	-1	1.2893	3.0133	.9087	30.22	.257294	2.4736	1.00000	.68074	4.82759	1.5835	4.425	11700.35
22														

*** OVERLAY(4,0) //THERMA *** . . . .

BODY POINT LOCATIONS AND SURFACE ENERGY BALANCE RESULTS AT
TIME = 31.0333 SEC

* DENOTES ANGLE LIMIT

POINT NUMBER	Z (INCHES)	Z-DOT USED	WALL TEMPERATURE (DEG R)	S-DOT TOTAL (IN/SEC)	S-DOT EROSION (IN/SEC)	PARTICLE ROUGHNESS (MILS)	B-PRIME THERMO-CHEM	CHH	CH (LBM/FT**2-SEC)	CHZ
1	2.18334	.79509	7588.18	79.5989E-02	0.	0.	28.9789E-02	48.8509E+03	26.7546E+00	31.87373
2	2.22927	.45648	7178.92	27.7014E-02	0.	0.	28.1713E-02	30.4165E+03	95.8738E-01	11.37345
3	2.30033	.76804	7347.76	53.5912E-02	0.	0.	27.5913E-02	58.4903E+03	18.9376E+00	22.39662
4	2.32090	.47708	7333.85	36.7471E-02	0.	0.	27.2730E-02	40.3189E+03	13.1369E+00	15.51014
5	2.35817	.56317	7412.56	44.0988E-02	0.	0.	27.2712E-02	48.5443E+03	15.7662E+00	18.61425
6	2.38377	.38187	7351.69	33.2602E-02	0.	0.	27.1805E-02	36.6508E+03	11.9309E+00	14.07926
7	2.40115	.40933	7467.48	36.3069E-02	0.	0.	27.1225E-02	40.3064E+03	13.0516E+00	15.39714
8	2.42757	.32099	7379.70	27.6810E-02	0.	0.	26.9968E-02	30.7571E+03	99.9710E-01	11.78577
9	2.45730	.40218	7453.13	37.7510E-02	0.	0.	27.1560E-02	41.8253E+03	13.5540E+00	15.99257
10	2.48862	.37697	7361.37	28.5605E-02	0.	0.	27.0505E-02	31.6442E+03	10.2993E+00	12.13953
11	2.51505	.22920	7338.82	19.3690E-02	0.	0.	26.7084E-02	21.7303E+03	70.7073E-01	8.32296
12	2.53868	.27046	7432.33	23.5704E-02	0.	0.	26.7992E-02	26.4591E+03	85.7528E-01	10.09888
13	2.56049	.27971	7355.79	21.5160E-02	0.	0.	26.7960E-02	24.0727E+03	78.2883E-01	9.21958
14	2.61389	.26904	7306.81	19.5982E-02	0.	0.	26.7748E-02	21.9009E+03	71.3665E-01	8.40346
15	2.65518	.31183	7351.01	22.3900E-02	0.	0.	26.8487E-02	24.9977E+03	81.3207E-01	9.57913
16	2.69436	.22421	7264.82	14.6968E-02	0.	0.	26.4837E-02	16.5851E+03	54.1062E-01	6.36109
17	2.74871	.22106	7247.05	14.0044E-02	0.	0.	26.4465E-02	15.8156E+03	51.6299E-01	6.06876
18	2.80403	.23231	7248.81	14.6798E-02	0.	0.	26.5790E-02	16.5494E+03	53.8502E-01	6.33425
19	2.85642	.24352	7267.44	16.1732E-02	0.	0.	26.8219E-02	18.2034E+03	58.7910E-01	6.92442
20	2.91183	.25183	7229.24	14.7724E-02	0.	0.	26.8239E-02	16.6470E+03	53.6950E-01	6.32427
21	2.96851	.24768	7206.74	13.8597E-02	0.	0.	26.8166E-02	15.6427E+03	50.3914E-01	5.93494
22	3.03183	.22257	7187.77	11.2013E-02	0.	0.	26.6161E-02	12.7299E+03	41.0326E-01	4.82752

TOTAL STAGNATION POINT RECESSION DUE TO EROSION ONLY = 0.0000 INCHES

TIME=, 30.95 SEC

FPA
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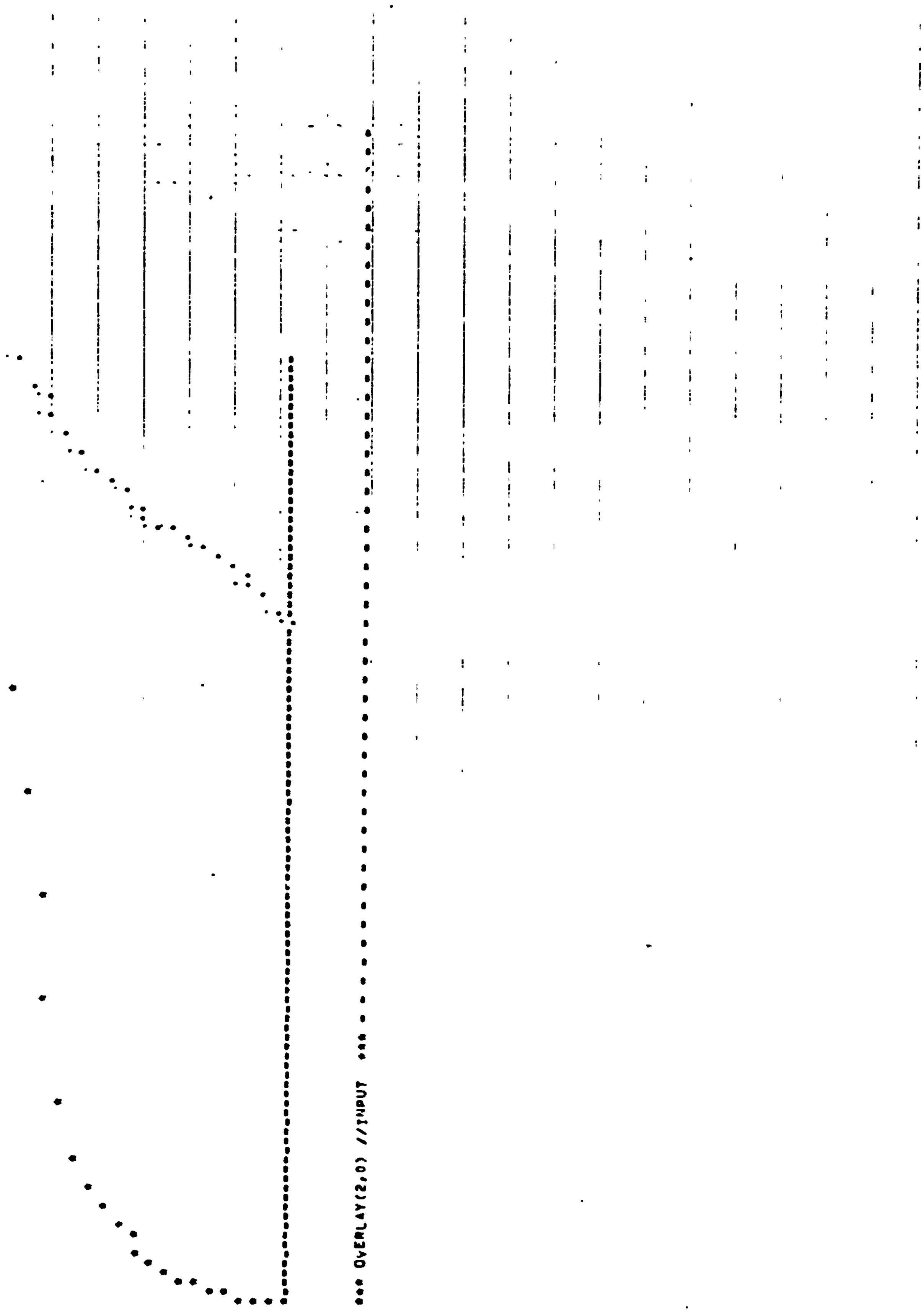


*** OVERLAY(2,0) //INPUT ***

Sample Problem No. 4

Sample Problem No. 4 is a transient clear air flight prediction of the 7° nosetip of Sample Problem No. 3.

This problem is basically a repeat of Problem No. 3, however, the transient in-depth conduction option is demonstrated.

```
  5  0
C   INPUT DATA
      TRANSIENT ANALYSIS
      OF FLIGHT FPA
      ATJ-S GRAPHITE                                   FPA
01
15.2          31.0               .5           .0
 -5  1  2  2  1  0  2  2
   .25             22.2
02
   15.2           150000.        22290.
   19.2           113000.        22290.
   20.2           102300.        22300.
   21.2            92000.        22300.
   22.2            82000.        22250.
   23.2            7 500.        22000.
   24.2           [illegible]2400.        21700.
   25.2            530[illegible].        21100.
   26.2            42600.        20250.
   27.2            35000.        19100.
   28.2            26000.        17700.
   29.2            18500.        16100.
   30.2            10800.        14400.
   31.0             6500.        12800.
   32.2                0.         9700.
03
SHEL     SOLI
   1       1      0     1   0   1
  23      10      3
1.          1.095
0.          0.              1.5708    1.
0.          1.
530.
.0625        7.             .25
   1
06
 1  117.  530.       0.0        0.7     0.7
 1

 1     .0004        .001
   460.   .15         .0027      .9
   960.   .31         .0168      .9
   1210.  .35         .0146      .9
   1460.  .38         .0131      .9
   1960.  .43         .0104      .9
   2460.  .465        .0086      .9
   2960.  .49         .0074      .9
   3460.  .505        .0065      .9
   3960.  .515        .0059      .9
   4460.  .52         .0055      .9
   4960.  .525        .0053      .9
   5460.  .525        .0052      .9
 91 9999. .525        .0052      .9
 09
   1
```

1 1.

.0100	.00000	4.000003325.6166	.000	5595.743	5595.743	1	C	*	.000
.0100	.00000	2.000003291.4387	.000	4584.223	4584.223	1	C	*	.000
.0100	.00000	1.800003284.6345	.000	4401.955	4401.955	1	C	*	.000
.0100	.00000	1.600003276.4585	.000	4191.066	4191.066	1	C	*	.000
.0100	.00000	1.400003266.4207	.000	3944.237	3944.237	1	C	*	.000
.0100	.00000	1.200003253.7492	.000	3651.409	3651.409	1	C	*	.000
.0100	.00000	1.000003237.1379	.000	3298.330	3298.330	1	C	*	.000
.0100	.00000	.800003214.1368	.000	2864.031	2864.031	1	C	*	.000
.0100	.00000	.600003179.3290	.000	2316.016	2316.016	1	C	*	.000
.0100	.00000	.500003153.4915	.000	1983.635	1983.635	1	C	*	.000
.0100	.00000	.400003116.3079	.000	1599.073	1599.073	1	C	*	.000
.0100	.00000	.350003090.1551	.000	1382.302	1382.302	1	C	*	.000
.0100	.00000	.300003059.1960	.000	1144.975	1144.975	1	C	*	.000
.0100	.00000	.250002998.2509	.000	880.830	880.830	1	C	*	.000
.0100	.00000	.220002941.0398	.000	703.014	703.014	1	C	*	.000
.0100	.00000	.200002873.5727	.000	568.912	568.912	1	C	*	.000
.0100	.00000	.190002812.8187	.000	490.765	490.765	1	C	*	.000
.0100	.00000	.180002665.8900	.000	382.537	382.537	1	C	*	.000
.0100	.00000	.17500 935.9883	.000	-166.833	-166.833	1	C	*	.000
.0100	.00000	.17000 871.8156	.000	-200.897	-200.897	1	C	*	.000
1.0000	.00000	4.000003986.7787	.000	5784.608	5784.608	1	C	*	.000
1.0000	.00000	2.000003930.7377	.000	4772.770	4772.770	1	C	*	.000
1.0000	.00000	1.800003919.7692	.000	4589.993	4589.993	1	C	*	.000
1.0000	.00000	1.600003906.6368	.000	4378.359	4378.359	1	C	*	.000
1.0000	.00000	1.400003890.5810	.000	4130.458	4130.458	1	C	*	.000
1.0000	.00000	1.200003870.4112	.000	3836.082	3836.082	1	C	*	.000
1.0000	.00000	1.000003844.1268	.000	3480.735	3480.735	1	C	*	.000
1.0000	.00000	.800003807.9968	.000	3043.019	3043.019	1	C	*	.000
1.0000	.00000	.600003753.8412	.000	2489.554	2489.554	1	C	*	.000
1.0000	.00000	.500003713.9969	.000	2153.084	2153.084	1	C	*	.000
1.0000	.00000	.400003657.2362	.000	1762.725	1762.725	1	C	*	.000
1.0000	.00000	.350003617.3928	.000	1541.949	1541.949	1	C	*	.000
1.0000	.00000	.300003563.1188	.000	1299.272	1299.272	1	C	*	.000
1.0000	.00000	.250003479.3765	.000	1027.102	1027.102	1	C	*	.000
1.0000	.00000	.220003393.5348	.000	841.391	841.391	1	C	*	.000
1.0000	.00000	.200003295.4901	.000	698.292	698.292	1	C	*	.000
1.0000	.00000	.190003207.2959	.000	612.293	612.293	1	C	*	.000
1.0000	.00000	.180002998.6084	.000	486.075	486.075	1	C	*	.000
1.0000	.00000	.175001185.8390	.000	-95.809	-95.809	1	C	*	.000
1.0000	.00000	.170001083.4739	.000	-141.289	-141.289	1	C	*	.000
10.0000	.00000	4.000004427.1046	.000	5921.222	5921.222	1	C	*	.000
10.0000	.00000	2.000004350.7841	.000	4899.925	4899.925	1	C	*	.000
10.0000	.00000	1.800004335.9129	.000	4715.167	4715.167	1	C	*	.000
10.0000	.00000	1.600004318.1419	.000	4501.168	4501.168	1	C	*	.000
10.0000	.00000	1.400004296.4675	.000	4250.411	4250.411	1	C	*	.000
10.0000	.00000	1.200004269.3253	.000	3952.549	3952.549	1	C	*	.000
10.0000	.00000	1.000004234.0984	.000	3592.893	3592.893	1	C	*	.000
10.0000	.00000	.800004185.9462	.000	3149.767	3149.767	1	C	*	.000
10.0000	.00000	.600004119.3455	.000	2589.345	2589.345	1	C	*	.000
10.0000	.00000	.500004062.0876	.000	2248.566	2248.566	1	C	*	.000
10.0000	.00000	.400003988.2183	.000	1853.031	1853.031	1	C	*	.000
10.0000	.00000	.350003936.7399	.000	1629.144	1629.144	1	C	*	.000
10.0000	.00000	.300003867.0729	.000	1382.716	1382.716	1	C	*	.000
10.0000	.00000	.250003760.5196	.000	1105.443	1105.443	1	C	*	.000
10.0000	.00000	.220003653.6239	.000	914.960	914.960	1	C	*	.000
10.0000	.00000	.200003530.0830	.000	766.422	766.422	1	C	*	.000

```
 10.0000  .00000   .190003421.1620 .000  675.551  675.551 1  C      *  .000
 10.0000  .00000   .180003167.3427 .000  537.650  537.550 1  C      *  .000
 10.0000  .00000   .175001371.4072 .000  -41.901  -41.901 1  C      *  .000
 10.0000  .00000   .170001235.0237 .000  -97.718  -97.718 1  C      *  .000
100.0000  .00000 4.000004977.5407 .000 6087.707 6087.707 1  C      *  .000
100.0000  .00000 2.000004867.2644 .000 5040.494 5040.494 1  C      *  .000
100.0000  .00000 1.800004845.6880 .000 4850.690 4850.690 1  C      *  .000
100.0000  .00000 1.600004819.9086 .000 4630.828 4630.828 1  C      *  .000
100.0000  .00000 1.400004785.4765 .000 4373.251 4373.251 1  C      *  .000
100.0000  .00000 1.200004749.2472 .000 4067.475 4067.475 1  C      *  .000
100.0000  .00000 1.000004699.5228 .000 3698.719 3698.719 1  C      *  .000
100.0000  .00000  .800004629.7045 .000 3245.377 3245.377 1  C      *  .000
100.0000  .00000  .600004528.7063 .000 2674.121 2674.121 1  C      *  .000
100.0000  .00000  .500004456.0787 .000 2328.097 2328.097 1  C      *  .000
100.0000  .00000  .400004354.9696 .000 1927.015 1927.815 1  C      *  .000
100.0000  .00000  .350004265.5280 .000 1701.816 1701.816 1  C      *  .000
100.0000  .00000  .300004192.7731 .000 1453.371 1453.371 1  C      *  .000
100.0000  .00000  .250004053.3203 .000 1173.626 1173.626 1  C      *  .000
100.0000  .00000  .220003915.9340 .000  980.357  980.357 1  C      *  .000
100.0000  .00000  .200003759.7963 .000  827.635  827.635 1  C      *  .000
100.0000  .00000  .190003624.1610 .000  732.212  732.212 1  C      *  .000
100.0000  .00000  .180003314.3614 .000  581.655  581.655 1  C      *  .000
100.0000  .00000  .175001630.3440 .000   34.688   34.688 1  C      *  .000
100.0000  .00000  .170001438.5134 .000  -38.261  -38.261 1  C      *  .000
500.0000  .00000 4.000005452.7057 .000 6225.165 6225.165 1  C      *  .000
500.0000  .00000 2.000005309.1459 .000 5138.615 5138.615 1  C      *  .000
500.0000  .00000 1.800005274.5576 .000 4941.085 4941.085 1  C      *  .000
500.0000  .00000 1.600005239.0687 .000 4712.312 4712.312 1  C      *  .000
500.0000  .00000 1.400005195.6924 .000 4444.533 4444.533 1  C      *  .000
500.0000  .00000 1.200005141.4257 .000 4127.279 4127.279 1  C      *  .000
500.0000  .00000 1.000005071.4274 .000 3746.099 3746.099 1  C      *  .000
500.0000  .00000  .800004977.1852 .000 3280.424 3280.424 1  C      *  .000
500.0000  .00000  .600004841.2934 .000 2699.451 2699.451 1  C      *  .000
500.0000  .00000  .500004745.6846 .000 2351.065 2351.065 1  C      *  .000
500.0000  .00000  .400004615.5325 .000 1951.367 1951.367 1  C      *  .000
500.0000  .00000  .350004527.9794 .000 1727.121 1727.121 1  C      *  .000
500.0000  .00000  .300004413.0676 .000 1481.500 1481.500 1  C      *  .000
500.0000  .00000  .250004243.9567 .000 1205.311 1205.311 1  C      *  .000
500.0000  .00000  .220004080.7421 .000 1013.670 1013.670 1  C      *  .000
500.0000  .00000  .200003898.3866 .000  860.399  860.399 1  C      *  .000
500.0000  .00000  .190003742.1505 .000  762.851  762.851 1  C      *  .000
500.0000  .00000  .180003391.9579 .000  604.424  604.424 1  C      *  .000
500.0000  .00000  .175001883.5403 .000  110.962  110.962 1  C      *  .000
500.0000  .00000  .170001628.6398 .000   18.164   18.164 1  C      *  .000

-1
C   END OF INPUT DATA
```

FPA

```
---GENERAL PROGRAM CONSTANTS---

(TRANSITION CRITERIA CONTROL)          TC = -5
(ENVIRONMENT CRITERIA CONTROL)        ENV =  1
(CURVE FIT CONTROL)                    CF =  2
(MATERIAL CONSTANT)                    MC =  2
(NO. OF TIME INTERVAL CHANGES)       NTIC =  1
(STEADY STATE FLAG)                   ISS =  0
(OUTPUT PRINT CONTROL)              IPRNT =  2
(INTERMEDIATE TIME PRINT CONTROL)   LPRNT =  2

---TIME INCREMENT INFORMATION---

INITIAL TIME (SEC) 15.2000           FINAL TIME (SEC) 31.0000

OUTPUT INTERVAL =   .5000 SEC FROM INITIAL TIME UNTIL 22.2000 SEC
OUTPUT INTERVAL =   .2500 SEC FROM  22.2000 SEC UNTIL FINAL TIME

TIME STEP STABILITY CRITERIA IN EFFECT
MINIMUM TIME STEP =1.0000E-06SECONDS
CTF =  1.300           STND = 75.000

---FLIGHT ENVIRONMENT---
```

TIME (SEC)	ALTITUDE (FT)	VELOCITY (FPS)
15.200	150000.0	22290.0
19.200	113000.0	22290.0
20.200	102300.0	22300.0
21.200	92000.0	22300.0
22.200	82000.0	22250.0
23.200	72500.0	22000.0
24.200	62400.0	21700.0
25.200	53000.0	21100.0
26.200	42600.0	20250.0
27.200	35000.0	19100.0
28.200	26000.0	17700.0
29.200	18500.0	16100.0
30.200	10800.0	14400.0
31.000	6500.0	12800.0
32.200	0.0	9700.0

BUILT-IN ATMOSPHERIC TABLE, 1962 U.S. STANDARD.

I	ALTITUDE(FT)	DENSITY(LBM/FT3)	PRESSURE(ATM)
1	0.	7.647400E-02	1.000000E+00
2	3.000000E+03	6.973400E-02	8.962400E-01
3	6.000000E+03	6.392500E-02	8.014300E-01
4	1.000000E+04	5.649300E-02	6.874300E-01
5	2.000000E+04	4.077300E-02	4.599100E-01
6	3.000000E+04	2.865700E-02	2.975400E-01
7	4.000000E+04	1.889510E-02	1.857700E-01
8	5.000000E+04	1.170900E-02	1.151200E-01
9	6.000000E+04	7.253000E-03	7.136600E-02
10	7.000000E+04	4.478700E-03	4.429000E-02
11	8.000000E+04	2.757600E-03	2.764900E-02
12	9.000000E+04	1.710300E-03	1.737900E-02
13	1.000000E+05	1.067600E-03	1.097700E-02
14	1.100000E+05	6.617000E-04	7.011200E-03
15	1.200000E+05	4.150600E-04	4.537100E-03
16	1.300000E+05	2.635300E-04	2.981500E-03
17	1.400000E+05	1.697400E-04	1.987600E-03
18	1.500000E+05	1.111900E-04	1.342900E-03
19	1.600000E+05	7.471300E-05	9.174400E-04
20	1.700000E+05	5.115000E-05	6.283400E-04
21	1.800000E+05	3.557800E-05	4.292400E-04
22	1.900000E+05	2.446300E-05	2.903500E-04
23	2.000000E+05	1.693700E-05	1.953700E-04
24	2.100000E+05	1.174900E-05	1.295400E-04
25	2.200000E+05	8.035600E-06	8.431900E-05
26	2.300000E+05	5.398800E-06	5.362700E-05
27	2.400000E+05	3.535300E-06	3.326900E-05
28	2.500000E+05	2.253000E-06	2.007400E-05
29	2.600000E+05	1.139000E-06	1.174000E-05
30	2.700000E+05	8.172000E-07	6.699600E-06
31	2.800000E+05	4.961000E-07	3.821100E-06
32	3.000000E+05	1.139000E-07	1.249900E-06
33	3.200000E+05	4.771000E-08	4.103400E-07
34	3.400000E+05	1.954000E-08	1.717000E-07
35	3.600000E+05	6.345000E-09	7.513300E-08
36	3.800000E+05	2.579000E-09	3.732200E-08
37	4.000000E+05	1.164000E-09	2.107100E-08
38	4.200000E+05	5.751000E-10	1.359700E-08
39	4.400000E+05	3.391000E-10	9.631500E-09
40	4.600000E+05	2.098000E-10	7.248500E-09

```
      ABLATE =  1
      MOVE =  1
      KAPFLA =  0
      IPHI =  1
      NOSYM =  0
      IZERO =  1
     NOSE RADIUS (FT) =  0.
     CONE ANGLE (RAD.)=  0.
      MAXIMUM X LENGTH (FT) =   1.5708
      SQUARE OF RATIO OF VERTICAL TO HORIZONTAL AXIS   1.0000

      JMAX = 23
      KMAX = 10
      LMAX =  5
  ZERO FLAGS-- IZFLG=      OTZFLG=     1
          SOLID BODY.  OMEGA =      1.57080

      TEMPERATURE INITIALIZED TO A CONSTANT  530.00

   EXTERNAL CONTOUR - RN2 =  6.25000E-02
                  THETA2 =   .12217
                  Z1 =   .25000

      AX =     1.095
      DX --    2.34487E-02   2.56743E-02   2.81155E-02   3.07865E-02   3.37112E-02   3.69138E-02   4.04206E-02
                4.42406E-02   4.84653E-02   5.30645E-02   5.81111E-02   6.36317E-02   6.96767E-02   7.62960E-02
                8.35441E-02   9.14808E-02    .10017         .10969         .12011         .13152         .14401
                 .15769

      AE =     1.000
      DETA --     .11111        .11111        .11111        .11111        .11111        .11111        .11111
                  .11111        .11111

      INTERNAL CONTOUR --

           BETAR --
  1.3708      1.5473        1.5217        1.4936        1.4623        1.4291
  1.7921      1.3517        1.3075        1.2590        1.2057        1.1478
  1.0842      1.0145         .93821        .85467        .76319        .66302
   .55333      .43322        .30170        .15769      -3.67500E-06

           ZZ --
 0.          0.            0.            0.            0.            0.
 0.          0.            0.            0.            0.            0.
 0.          0.            0.            0.            0.            0.
 0.          0.            0.            0.            0.

           KAPLAM --
  1.0000      1.0000        1.0000        1.0000        1.0000        1.0000
  1.0000      1.0000        1.0000        1.0000        1.0000        1.0000
  1.0000      1.0000        1.0000        1.0000        1.0000        1.0000
  1.0000      1.0000        1.0000        1.0000        1.0000

 TIMCYC =           0 TIME =     0.           DTIME =     0.
 AXIAL RECESSION =     0.        AXIAL RECESSION RATE =      0.
```

---MATERIAL PROPERTIES---

******* M A T E R I A L   N U M B E R   1 *******

---SURFACE ROUGHNESS---

ROUGHNESS HEIGHT FOR LAMINAR HEATING AND TRANSITION   K-LAM = .00040 (INCH)
ROUGHNESS HEIGHT FOR TURBULENT HEATING   K-TURB = .00100 (INCH)

FLAG FOR TYPE OF ROUGH TURBULENT HEATING   JROUGH = 1

---THERMAL PROPERTIES---

RHO = 117.00
TFO = 530.00
HFO = 0.00
TBRPL = .70
TBRPT = .70

TEMPERATURE (DEG F)	SPECIFIC HEAT (BTU/LB-DEG)	CONDUCTIVITY (BTU/FT-SEC-DEG)	SENSIBLE ENTHALPY (BTU/LB)	EMISSIVITY
460.00	.1500	.0027000	-16.10	.9000
960.00	.3100	.0168000	98.90	.9000
1210.00	.3500	.0146000	181.40	.9000
1460.00	.3900	.0131000	272.65	.9000
1960.00	.4360	.0104000	475.15	.9000
2460.00	.4650	.0084000	698.90	.9000
2960.00	.4900	.0074000	937.65	.9000
3460.00	.5050	.0065000	1186.40	.9000
3760.00	.5150	.0059000	1441.40	.9000
4060.00	.5200	.0055000	1700.15	.9000
4960.00	.5250	.0053000	1961.40	.9000
5460.00	.5250	.0052000	2223.90	.9000
7997.00	.5250	.0052000	4606.87	.9000

---SURFACE EQUILIBRIUM DATA---

MAT = 1
NBPF = 0
CPM = 1.00000

M-DOT-GAS/CM = 0.0000 PRESSURE = .0100 ATM

TEMP	BPRIM	HCW	TSEN	TCHEM	SPECIE
1560.2641	.1700	316.9136	-361.4146	476.9427	C
1684.7789	.1750	363.6855	-300.2994	416.4968	C
4794.6020	.1800	1877.0695	680.5556	-470.6361	C
5044.0737	.1900	2015.5147	843.3770	-668.2710	C
5172.8307	.2000	2072.8262	1024.0416	-810.2647	C
5293.8716	.2200	2134.6824	1265.4252	-1073.7486	C
5394.8514	.2500	2190.7471	1565.4940	-1434.1897	C
5497.5528	.3000	2243.6152	2060.9550	-2006.1569	C
5562.2702	.3500	2277.5965	2493.1436	-2561.8351	C
5604.4982	.4000	2302.3866	2878.3314	-3108.7093	C
5676.2847	.5000	2337.4495	3579.5430	-4187.0898	C
5722.7922	.6000	2361.8559	4160.4238	-5253.0065	C
5784.3462	.8000	2394.7573	5155.2558	-7363.6530	C
5826.8482	1.0000	2416.4953	5936.9940	-8457.4927	C
5856.7486	1.2000	2432.1930	6572.5362	-11540.9480	C
5879.5573	1.4000	2444.1676	7099.6266	-13617.2693	C
5897.6253	1.6000	2453.6533	7543.9158	-15689.[illegible]436	C
5912.3401	1.8000	2461.3796	7923.5190	-17755.3699	C
5924.5807	2.0000	2467.9096	8251.6014	-19819.1851	C
5986.4609	4.0000	2500.2967	10072.3378	-40360.5003	C

H-DOT-GAS/CM = 0.0000   PRESSURE = 1.0000 ATM

TEMP	WPRIM	HCH	TSEN	TCHEM	SPECIE
1351.2550	.1700	371.2125	-251.3232	377.5571	C
2134.5102	.1750	553.2435	-172.4562	299.4536	C
5327.4951	.1800	2191.0249	874.0350	-638.0280	C
5773.1326	.1900	2389.2906	1102.1271	-857.7556	C
5931.8822	.2000	2471.6391	1250.9256	-1013.9831	C
6110.1620	.2200	2565.2354	1514.5038	-1283.3429	C
6242.8777	.2500	2645.4109	1844.7836	-1649.6268	C
6413.6135	.3000	2724.5473	2338.6896	-2222.9323	C
6511.3070	.3500	2775.8362	2775.5082	-2775.3930	C
6584.0252	.4000	2813.4492	3172.0050	-3316.6717	C
6645.1914	.5000	2867.1271	3475.5512	-4379.7633	C
6756.9142	.6000	2904.7799	4481.1972	-5427.0476	C
6850.3242	.8000	2955.4570	5477.4342	-7494.6160	C
6919.4242	1.0000	2991.4954	6265.3230	-9540.5462	C
6966.7402	1.2000	3014.9380	6903.0476	-11572.9584	C
7003.0454	1.4000	3033.9993	7434.4244	-13595.9799	C
7031.9462	1.6000	3047.1718	7831.0462	-15612.0455	C
7055.5840	1.8000	3061.5819	8201.9871	-17622.7173	C
7075.3277	2.0000	3071.9471	8590.9860	-19629.0637	C
7176.2017	4.0000	3124.9659	10412.2744	-39561.9445	C

H-DOT-GAS/CM = 0.0000   PRESSURE = 10.0000 ATM

TEMP	WPRIM	HCH	TSEN	TCHEM	SPECIE
2223.0427	.1700	592.8616	-175.8924	306.5876	C
2468.5330	.1750	702.9745	-75.4218	211.6412	C
5761.2149	.1800	2350.5319	957.7700	-718.8716	C
6151.0915	.1900	2590.3901	1215.7918	-954.8546	C
6354.1094	.2100	2693.3244	1379.5596	-1115.5058	C
6576.5230	.2200	2910.0740	1646.7299	-1391.0355	C
6768.9353	.2500	2911.0910	1939.7974	-1759.4740	C
6962.7312	.3000	3011.7939	2483.8388	-2332.0203	C
7046.1319	.3500	3077.6172	2932.4572	-2981.6532	C
7178.7929	.4000	3126.2653	3335.4558	-3419.1316	C
7311.7577	.5000	3190.0724	4047.4139	-4473.0916	C
7405.8219	.6000	3245.4565	4660.8219	-5510.0397	C
7534.7032	.8000	3313.1142	5669.5306	-7554.7498	C
7621.3771	1.0000	3357.0231	6467.2074	-9575.7318	C
7680.7855	1.2000	3391.9124	7114.5992	-11581.7991	C
7714.6415	1.4000	3417.5618	7650.7398	-13577.1930	C
7772.6554	1.6000	3438.0441	8102.1024	-15560.5957	C
7804.6412	1.8000	3454.8377	8487.3006	-17545.7339	C
7831.4114	2.0000	3468.8910	8819.8850	-19521.8131	C
7948.7883	4.0000	3541.0138	10658.1996	-39126.9426	C

M-DOT-GAS/CM = 0.0000 PRESSURE = 100.0000 ATM

TEMP	APRIM	HCH	TSEN	TCHEM	SPECIE
2530.3241	.1700	761.6523	-60.8694	209.8816	C
2934.6192	.1750	925.5307	62.4344	88.6027	C
5965.4505	.1800	2469.4715	1046.2790	-757.3373	C
6523.4898	.1900	2762.2321	1317.9516	-1034.7740	C
6767.6333	.2000	2910.4075	1489.7430	-1205.6101	C
7048.6612	.2200	3057.9576	1764.6426	-1480.1173	C
7295.9765	.2500	3187.7877	2112.5269	-1903.7116	C
7544.9916	.3000	3319.5706	2619.0078	-2405.0170	C
7713.9504	.3500	3407.2240	3063.2693	-2942.8845	C
7838.9453	.4000	3472.8463	3470.0470	-3468.9553	C
8020.9417	.5000	3564.3944	4190.5746	-4501.6647	C
8151.6713	.6000	3637.0275	4813.4178	-5519.2520	C
8333.4681	.8000	3732.4709	5901.6796	-7529.0749	C
8457.3410	1.0000	3797.5049	6657.6942	-9517.9844	C
8543.6050	1.2000	3845.4386	7321.4559	-11392.6747	C
8619.2937	1.4000	3882.5292	7871.4518	-13456.9035	C
8675.8355	1.6000	3912.2135	8335.4904	-15412.7332	C
8722.2584	1.8000	3936.5752	8731.2420	-17361.6423	C
8761.0759	2.0000	3956.9649	9072.8892	-19334.7379	C
8959.5733	4.0000	4061.1760	10957.8726	-38544.6592	C

M-DOT-GAS/CM = 0.0000 PRESSURE = 500.0000 ATM

TEMP	APRIM	HCH	TSEN	TCHEM	SPECIE
2931.5516	.1700	924.0659	32.6952	119.9378	C
3390.3725	.1750	1151.7403	199.7316	-33.1266	C
6105.5242	.1800	2562.8002	1087.7632	-922.4925	C
6735.8709	.1900	2893.7322	1373.1318	-1094.2177	C
7017.0959	.2000	3041.3753	1548.7182	-1250.1969	C
7345.3358	.2200	3213.7313	1824.6067	-1519.0950	C
7639.1221	.2500	3367.7391	2169.5595	-1969.9650	C
7843.5217	.3000	3527.7039	2646.7030	-2409.3853	C
8150.3429	.3500	3636.3105	3109.8178	-2924.1948	C
8307.9585	.4000	3719.0782	3512.4606	-3429.9136	C
8542.2323	.5000	3842.0719	4231.9170	-4420.8373	C
8714.3209	.6000	3932.4232	4859.0119	-5411.9650	C
8958.7334	.8000	4066.8100	5904.7632	-7373.9017	C
9124.5693	1.0000	4149.8449	6742.9782	-9336.0575	C
9254.5643	1.2000	[illegible]	7429.1022	-11284.7491	C
9352.2463	1.4000	4267.3293	8100.1590	-13226.1215	C
9430.3237	1.6000	[illegible]	8392.1516	-15160.3083	C
9494.2037	1.8000	[illegible]	8693.9530	-17097.7259	C
9547.3626	2.0000	4369.8178	9249.5070	-19908.8852	C
9814.9703	4.0000	4510.2069	11205.2970	-37985.6575	C

```
*** OVERLAY(3,0) //ENVIRT ***
```

*** OVERLAY(3,1) //VORT1 *** . . . .

SHOULDER POINT = 22   SONIC POINT = 9

*** STAGNATION POINT ENVIRONMENT HISTORY FOR THE INITIAL BODY SHAPE ***

	- -STAGNATION POINT QUANTITIES- -			- - -FREESTREAM QUANTITIES- - -		
TIME (SEC)	PRESSURE (ATM)	ENTHALPY (BTU/LBM)	HEAT TRANS.COEFF. (LBM/FT2-SEC)	VELOCITY (FT/SEC)	DENSITY (LBM/FT3)	PRESSURE (ATM)
15.2000	7.953E-01	1.005E+04	1.705E-01	2.229E+04	1.112E-04	1.303E-03
19.2000	4.095E+00	1.004E+04	3.988E-01	2.229E+04	5.771E-04	6.153E-03
20.2000	6.743E+00	1.014E+04	5.145E-01	2.230E+04	9.574E-04	9.915E-03
21.2000	1.125E+01	1.004E+04	6.566E-01	2.230E+04	1.556E-03	1.586E-02
22.2000	1.753E+01	9.995E+03	8.325E-01	2.225E+04	2.506E-03	2.520E-02
23.2000	2.712E+01	9.742E+03	1.039E+00	2.200E+04	3.967E-03	3.937E-02
24.2000	4.295E+01	9.519E+03	1.311E+00	2.170E+04	6.465E-03	6.365E-02
25.2000	6.362E+01	9.006E+03	1.603E+00	2.110E+04	1.014E-02	9.974E-02
26.2000	9.521E+01	8.286E+03	1.983E+00	2.025E+04	1.668E-02	1.600E-01
27.2000	1.191E+02	7.379E+03	2.229E+00	1.910E+04	2.327E-02	2.351E-01
28.2000	1.434E+02	6.372E+03	2.457E+00	1.770E+04	3.300E-02	3.542E-01
29.2000	1.552E+02	5.299E+03	2.541E+00	1.610E+04	4.262E-02	4.885E-01
30.2000	1.534E+02	4.270E+03	2.559E+00	1.480E+04	5.503E-02	6.660E-01
31.0000	1.439E+02	3.399E+03	2.403E+00	1.280E+04	6.294E-02	7.863E-01
32.2000	9.975E+01	2.004E+03	1.917E+00	9.700E+03	7.647E-02	1.000E+00

*** OVERLAY(3,0) //ENVIRT *** . . . .

*** OVERLAY(3,2) //VORT19 *** . . . .

NEW CURVE FIT DONE TO BODY POINTS
9CURVES FIT TO, 71 POINTS

CURVE	A	B	C	AUC(I+1)
1	16.09904E+04	16.21716E+04	-43.93162E-15	11.18514E-03
2	-80.60312E+03	16.77777E+04	-31.35220E+00	22.33695E-03
3	-13.32800E+04	17.01310E+04	-57.63479E+00	33.61450E-03
4	-60.47898E+04	20.14301E+04	-59.04099E+01	45.01371E-03
5	-82.26507E+04	22.14178E+04	-10.39727E+02	58.77224E-03
6	21.92561E+05	-13.29936E+04	93.75342E+02	70.81644E-03
7	-36.62574E+05	49.64760E+03	-19.98797E+03	93.43396E-03
8	-20.11529E+03	15.81732E+03	11.81035E+03	28.69617E-02
9	-10.40704E+04	56.83001E+03	51.02961E+02	29.27011E-02

*** OVERLAY(3,3) //VORT3 *** . . . .

O U T P U T

*************** *******************
* VIST CALLED AT FIRST TIME STEP *
****

TABLE-1 SUMMARY INFORMATION

ITERATION NO. ITS	ITERATION NO. ITS	TIMEP (SEC)	ALTITUDE ALT (FT)	FREESTREAM MACH-NO. M-INF	STAGNATION PT. PRESSURE PT2 (ATM)	STAGNATION PT. ENTHALPY HO (BTU/LBM)
1	0	15.2000	150000	20.782	.7953	10045.7

STAG. PT. RECESSION SPREC (INCH)	CURRENT NOSE RADIUS RN (INCH)	EFFECTIVE NOSE RADIUS R-EFF (INCH)	STAGNATION PT. HEAT TRANS. COEF. SPHTC (LBM/FT2-SEC)	TRANSITION STREAM LENGTH S-TRAN (INCH)	SONIC PT. AXIAL LENGTH X-STAR (INCH)	SONIC PT. RADIAL LENGTH Y-STAR (INCH)
0.0000	.7933	.5084	.1877	0.0000	.1623	.4622

TABLE-2 SUMMARY DISTRIBUTION TABLE

J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, LAM = TRANSITION FLAG

J	I	LAM	STREAM LENGTH S (INCH)	AXIAL LENGTH X (INCH)	RADIAL LENGTH Y (INCH)	BODY ANGLE (DEG)	PRESSURE RATIO PE/PT2	EDGE MACH ME	ROUGHNESS HEIGHT K MIL	LAMINAR CHO CHO-LAM (LBM/FT2-SEC)	TURBULENT CHO CHO-TURB	HEATING AUG. PARAMETER FKR	MOMENTUM THICKNESS THETA (MIL)	MOMENTUM THICKNESS REYNOLDS NO. RE-THETA
	1	1	0.0000	0.0000	0.0000	90.00	1.000000	0.0000	.40000	.18749	.18769	1.0000	2.733	0.00
1	6	1	.0704	.0033	.0703	84.49	.989263	.1554	.40000	.18711	.18506	1.0000	2.739	3.10
2	11	1	.1477	.0145	.1468	78.56	.954452	.3292	.40000	.18335	.18435	1.0000	2.788	6.66
3	16	1	.2330	.0359	.2294	72.01	.890539	.5234	.40000	.17492	.18191	1.0000	2.907	10.90
4	21	1	.3279	.0706	.3177	64.72	.793979	.7420	.40000	.16123	.17371	1.0000	3.123	15.82
5	26	1	.4343	.1223	.4106	56.52	.664902	.9916	.40000	.14191	.15827	1.0000	3.499	21.34
6	31	1	.5553	.1986	.5062	47.16	.499187	1.2724	.40000	.11392	.12908	1.0000	4.273	26.04
7	36	1	.6963	.3012	.5929	36.16	.330457	1.5661	.40000	.09220	.09249	1.0000	5.767	31.85
8	42	1	.8486	.4501	.6874	22.32	.145736	2.0664	.40000	.04030	.04723	1.0000	10.554	35.27
9	45	1	1.1077	.6816	.7472	10.74	.071527	2.5073	.40000	.02247	.02600	1.0000	18.238	37.33
10	47	1	1.3838	.9556	.7809	7.00	.068253	2.6179	.40000	.01486	.01833	1.0000	26.625	39.20
11	49	1	1.6289	1.1989	.8108	7.00	.043660	2.6788	.40000	.01343	.01669	1.0000	29.264	40.72
12	51	1	1.8485	1.4167	.8375	7.00	.040247	2.7299	.40000	.01238	.01547	1.0000	31.538	41.88
13	53	1	2.0472	1.6141	.8617	7.00	.037623	2.7731	.40000	.01159	.01455	1.0000	33.486	42.80
14	55	1	2.2288	1.7703	.8839	7.00	.035579	2.8101	.40000	.01098	.01388	1.0000	35.156	43.55
15	57	1	2.3965	1.9609	.9043	7.00	.033953	2.8420	.40000	.01050	.01329	1.0000	36.592	44.18
16	59	1	2.5536	2.1167	.9234	7.00	.032632	2.8698	.40000	.01010	.01285	1.0000	37.839	44.73
17	61	1	2.7026	2.2647	.9416	7.00	.031534	2.8946	.40000	.00977	.01249	1.0000	38.938	45.23
18	63	1	2.8466	2.4075	.9592	7.00	.030575	2.9169	.40000	.00949	.01218	1.0000	39.926	45.68
19	65	1	2.9885	2.5483	.9764	7.00	.029748	2.9374	.40000	.00923	.01191	1.0000	40.840	46.10
20	67	1	3.1319	2.6907	.9939	7.00	.029010	2.9567	.40000	.00899	.01167	1.0000	41.719	46.51
21														

```
                                                                                                  FPA
                                                                                    TIMF=,  15.20 SEC  PAGE  9
   69   1   3.2914   2.8591   1.0121   7.00   .028280   2.9754   .40000     .00876   .01143   1.0000   42.608     46.93
22 71   1   3.4435   3.0000   1.0319   7.00   .027537   3.0545   .40000     .00881   .01118   1.0000   42.297     47.36
23
*** OVERLAY(1,0) //THERM  *** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

          DLTE          DLTIS        DLTC        DLTC1         DLTC2        DLTL          DLTS        DTH
      5.00000E-01 2.25729E-02 9.71515E-02 0.              0.           9.90000E+01 0.          2.25729E-02

STAGNATION POINT TEMPERATURE =   5339.8153

NSTEP =  1      TIME =15.200CE+00      DTIME =22.5729E-03

DLTS =10.8156E+01       DLTC =29.0910E-02

 DS
  2.5000E-01  2.4979E-01  2.4909E-01  2.4774E-01  2.4555E-01  2.4223E-01  2.3739E-01  2.3041E-01  2.2008E-01  2.0298E-01
  1.8237E-01  1.6460E-01  1.4925E-01  1.3600E-01  1.2458E-01  1.1479E-01  1.0649E-01  9.9560E-02  9.3948E-02  8.9653E-02
  8.6745E-02  8.5404E-02  8.5992E-02

 SDOT
  0.          2.5662E-04  2.5330E-04  2.1997E-04  2.2018E-04  1.9309E-04  1.5011E-04  1.1040E-04  5.4422E-05  2.4734E-05
  1.6046E-05  1.4439E-05  1.3272E-05  1.2397E-05  1.1722E-05  1.1188E-05  1.0753E-05  1.0390E-05  1.0077E-05  9.7983E-06
  9.5308E-06  9.2941E-06  9.3354E-06

 QW
  0.          1.2111E+03  1.2011E+03  1.1803E+03  1.1597E+03  1.0658E+03  9.2131E+02  7.0763E+02  4.1234E+02  2.1039E+02
  1.3030E+02  1.2581E+02  1.1595E+02  1.0851E+02  1.0275E+02  9.8179E+01  9.4452E+01  9.1331E+01  8.8636E+01  8.6227E+01
  8.3986E+01  8.1784E+01  8.2200E+01


T-DIST. IN L=1 PLANE
  5.3398E+03  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  5.3124E+03  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  5.2197E+03  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  5.0381E+03  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  4.7267E+03  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  4.2354E+03  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  3.4826E+03  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  2.4893E+03  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  1.4066E+03  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  8.1458E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  7.1842E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  7.0018E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  6.8683E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  6.7677E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  6.6899E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  6.6280E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  6.5776E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  6.5354E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  6.4984E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  6.4664E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  6.4360E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  6.4063E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
  6.4119E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02

          DLTE          DLTIS        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
      4.77427E-01 2.25729E-02 2.80910E-01 2.80910E-01 5.51909E-04 9.90000E+01 1.08156E+02 3.51825E-04
```

```
TIMCYC =         2 TIME =      15.2226     DTIME =    3.518254E-04
AXIAL RECESSION =    0.           AXIAL RECESSION RATE =    0.

STAGNATION POINT TEMPERATURE =   5094.9413

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
  4.77075E-01 2.25729E-02 3.11305E-01 3.11305E-01 1.09090E-04 9.90000E+01 1.08363E+02 1.09071E-04


TIMCYC =         3 TIME =      15.2229     DTIME =    1.090797E-04
AXIAL RECESSION =   -6.290806E-07 AXIAL RECESSION RATE =    0.

STAGNATION POINT TEMPERATURE =   5067.1756

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
  4.76966E-01 2.25729E-02 3.01545E-01 1.41865E-04 1.28687E-04 9.90000E+01 1.07798E+02 1.28666E-04


TIMCYC =         4 TIME =      15.2230     DTIME =    1.286664E-04
AXIAL RECESSION =   -5.958830E-07 AXIAL RECESSION RATE =    2.576935E-04

STAGNATION POINT TEMPERATURE =   5067.1208

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
  4.76837E-01 2.25729E-02 3.04512E-01 1.67266E-04 2.61568E-04 9.90000E+01 1.07811E+02 1.67253E-04


TIMCYC =         5 TIME =      15.2232     DTIME =    1.672527E-04
AXIAL RECESSION =   -5.627310E-07 AXIAL RECESSION RATE =    2.576524E-04

STAGNATION POINT TEMPERATURE =   5064.2113

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
  4.76670E-01 2.25729E-02 3.03565E-01 2.17380E-04 1.00348E-03 9.90000E+01 1.07814E+02 2.17360E-04


TIMCYC =         6 TIME =      15.2233     TIME =    2.173599E-04
AXIAL RECESSION =   -5.196398E-07 AXIAL RECESSION RATE =    2.576459E-04

STAGNATION POINT TEMPERATURE =   5066.4510

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
  4.76453E-01 2.25725E-02 3.03731E-01 2.82573E-04 3.10881E-03 9.90000E+01 1.07813E+02 2.82426E-04
```

```
IMCYC =        7 TIME =     15.2235      DTIME =     2.924261E-04
AXIAL RECESSION =   -2.636376E-07 AXIAL RECESSION RATE =     2.576472E-04

STAGNATION POINT TEMPERATURE =    5064.4211

     DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
 4.   76E-01 2.25729E-02 3.03706E-01 3.67153E-04 3.62652E-03 9.00000E+01 1.07813E+02 3.67132E-04

IMCYC =        8 TIME =     15.2238      DTIME =     3.671322E-04
AXIAL RECESSION =   -3.009714E-07 AXIAL RECESSION RATE =     2.576470E-04

STAGNATION POINT TEMPERATURE =    5064.8554

     DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
 4.75803E-01 2.25729E-02 3.03412E-01 4.77288E-04 5.53408E-03 9.00000E+01 1.07813E+02 4.77235E-04

IMCYC =        9 TIME =     15.2242      DTIME =     4.772350E-04
AXIAL RECESSION =   -2.962805E-07 AXIAL RECESSION RATE =     2.576480E-04

STAGNATION POINT TEMPERATURE =    5065.4130

     DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
 4.75326E-01 2.25729E-02 3.03679E-01 6.20432E-04 9.56944E-03 9.00000E+01 1.07812E+02 6.19721E-04

IMCYC =       10 TIME =     15.2247      DTIME =     6.197211E-04
AXIAL RECESSION =   -1.733213E-07 AXIAL RECESSION RATE =     2.576491E-04

STAGNATION POINT TEMPERATURE =    5066.1263

     DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
 4.74706E-01 2.25729E-02 3.02879E-01 8.05682E-04 1.12408E-02 9.00000E+01 1.07812E+02 8.04587E-04

IMCYC =       11 TIME =     15.2253      DTIME =     8.045871E-04
AXIAL RECESSION =   -1.364977E-08 AXIAL RECESSION RATE =     2.576506E-04

STAGNATION POINT TEMPERATURE =    5067.1586

     DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
 4.73902E-01 2.25729E-02 3.03768E-01 1.04605E-03 1.59783E-02 9.00000E+01 1.07811E+02 1.04384E-03
```

```
IMCYC =          12 TIME =      15.2261      CTIME =     1.043837E-03
XIAL RECESSION =     1.936543E-07 AXIAL RECESSION RATE =     2.576527E-04

TAGNATION POINT TEMPERATURE =    5068.3411

          DLTE         DLTI3        DLTC         DLTC1        DLTC2        DLTL         DLTS         DTH
     4.72854E-01 2.25729E-02 3.01737E-01 1.35711E-03 7.89844E-03 9.90000E+01 1.07810E+02 1.35489E-03

IMCYC =          13 TIME =      15.2271      CTIME =     1.354894E-03
XIAL RECESSION =     4.626042E-07 AXIAL RECESSION RATE =     2.576551E-04

TAGNATION POINT TEMPERATURE =    5070.1270

          DLTE         DLTI3        DLTC         DLTC1        DLTC2        DLTL         DLTS         DTH
     4.71503E-01 2.25729E-02 3.03345E-01 1.76161E-03 6.63228E-03 9.90000E+01 1.07808E+02 1.75934E-03

IMCYC =          14 TIME =      15.2285      CTIME =     1.759340E-03
XIAL RECESSION =     8.117045E-07 AXIAL RECESSION RATE =     2.576589E-04

TAGNATION POINT TEMPERATURE -    5072.0345

          DLTE         DLTI3        DLTC         DLTC1        DLTC2        DLTL         DLTS         DTH
     4.69744E-01 2.25729E-02 2.94204E-01 2.28708E-03 5.55433E-03 9.90000E+01 1.07806E+02 2.28031E-03

IMCYC =          15 TIME =      15.2303      CTIME =     2.280309E-03
XIAL RECESSION =     1.245021E-06 AXIAL RECESSION RATE =     2.576627E-04

TAGNATION POINT TEMPERATURE =    5075.1477

          DLTE         DLTI3        DLTC         DLTC1        DLTC2        DLTL         DLTS         DTH
     4.67463E-01 2.25729E-02 3.06353E-01 2.96512E-03 5.24236E-03 9.4  30E+01 1.07803E+02 2.95863E-03

IMCYC =          16 TIME =      15.2325      CTIME =     2.958629E-03
XIAL RECESSION =     1.852586E-06 AXIAL RECESSION RATE =     2.576692E-04

TAGNATION POINT TEMPERATURE =    5078.1384

          DLTE         DLTI3        DLTC         DLTC1        DLTC2        DLTL         DLTS         DTH
     4.64505E-01 2.25729E-02 2.93756E-01 3.84711E-03 3.82035E-03 9.90000E+01 1.07800E+02 3.80702E-03
```

```
IMCYC =        17 TIME =      15.2355     DTIME =    3.807416E-03
XIAL RECESSION =    2.614951E-06 AXIAL RECESSION RATE =    2.576751E-04

TAGNATION POINT TEMPERATURE =    5093.5820

          DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
     4.60097E-01 2.25729E-02 3.11779E-01 4.95173E-03 3.50017E-03 9.90000E+01 1.07795E+02 3.49013E-03


IMCYC =        18 TIME =      15.2393     DTIME =    3.490132E-03
XIAL RECESSION =    3.596072E-06 AXIAL RECESSION RATE =    2.576866E-04

TAGNATION POINT TEMPERATURE =    5088.1656

          DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
     4.57207E-01 2.25729E-02 2.93331E-01 4.53879E-03 3.21540E-03 9.90000E+01 1.07791E+02 3.19725E-03


IMCYC =        19 TIME =      15.2428     DTIME =    3.197253E-03
XIAL RECESSION =    4.495463E-06 AXIAL RECESSION RATE =    2.576956E-04

TAGNATION POINT TEMPERATURE =    5094.6645

          DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
     4.54010E-01 2.25729E-02 3.05931E-01 4.15853E-03 4.32112E-03 9.90000E+01 1.07785E+02 4.12736E-03


IMCYC =        20 TIME =      15.2460     DTIME =    4.127363E-03
XIAL RECESSION =    5.319424E-06 AXIAL RECESSION RATE =    2.577090E-04

TAGNATION POINT TEMPERATURE =    5099.0435

          DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
     4.07883E-01 2.25729E-02 2.80524E-01 5.36740E-03 3.95955E-03 9.90000E+01 1.07781E+02 3.94634E-03


IMCYC =        21 TIME =      15.2501     DTIME =    3.946339E-03
XIAL RECESSION =    6.383117E-06 AXIAL RECESSION RATE =    2.577173E-04

TAGNATION POINT TEMPERATURE =    5106.3900

          DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
     4.45934E-01 2.25729E-02 3.03755E-01 5.13317E-03 4.43521E-03 9.90000E+01 1.07774E+02 4.41521E-03
```

```
NCYC =        22 TIME =      15.2541     DTIME =    4.415211E-03
IAL RECESSION =    7.400217E-05 AXIAL RECESSION RATE =    2.577326E-04

AGNATION POINT TEMPERATURE =   5111.8120

         DLTE         DLTIS         DLTC         DLTC1        DLTC2         DLTL          DLTS          DTH
   4.41521E-01 2.25729E-02 2.86023E-01 5.74220E-03 4.27258E-03 9.90000E+01 1.07769E+02 4.24539E-03


NCYC =        23 TIME =      15.2585     DTIME =    4.245395E-03
IAL RECESSION =    8.538207E-06 AXIAL RECESSION RATE =    2.577430E-04

AGNATION POINT TEMPERATURE =   5119.2745

         DLTE         DLTIS         DLTC         DLTC1        DLTC2         DLTL          DLTS          DTH
   4.37274E-01 2.25729E-02 3.00072E-01 5.52222E-03 5.10664E-03 9.90000E+01 1.07763E+02 5.08460E-03


NCYC =        24 TIME =      15.2627     DTIME =    5.084601E-03
IAL RECESSION =    9.632493E-06 AXIAL RECESSION RATE =    2.577584E-04

AGNATION POINT TEMPERATURE =   5125.3695

         DLTE         DLTIS         DLTC         DLTC1        DLTC2         DLTL          DLTS          DTH
   4.32191E-01 2.25729E-02 2.82285E-01 6.61312E-03 4.62238E-03 9.90000E+01 1.07757E+02 4.59778E-03


NCYC =        25 TIME =      15.2676     DTIME =    4.597777E-03
IAL RECESSION =    1.094315E-05 AXIAL RECESSION RATE =    2.577703E-04

AGNATION POINT TEMPERATURE =   5133.3996

         DLTE         DLTIS         DLTC         DLTC1        DLTC2         DLTL          DLTS          DTH
   4.27593E-01 2.25729E-02 2.95151E-01 5.98085E-03 5.66664E-03 9.90000E+01 1.07750E+02 5.62623E-03


NCYC =        26 TIME =      15.2724     DTIME =    5.626227E-03
IAL RECESSION =    1.212840E-05 AXIAL RECESSION RATE =    2.577860E-04

AGNATION POINT TEMPERATURE =   5137.5596

         DLTE         DLTIS         DLTC         DLTC1        DLTC2         DLTL          DLTS          DTH
   4.21967E-01 2.25729E-02 2.75748E-01 7.31647E-03 5.33805E-03 9.90000E+01 1.07743E+02 5.27459E-03


NCYC =        27 TIME =      15.2780     DTIME =    5.274586E-03
```

```
IAL RECESSION =    1.357824E-05 AXIAL RECESSION RATE =    2.578C01E-04

AGNATION POINT  TEMPERATURE =   5148.5565

        DLTE        DLTIS        DLTC         DLTC1        DLTC2        DLTL         DLTS        DTH
   4.16592E-01 2.25729E-02 2.90924E-01 6.68286E-03 6.23798E-03 9.90000E+01 1.07735E+02 6.21929E-03


MCYC =        28 TIME =     15.2823     DTIME =     6.219291E-03
IAL RECESSION =    1.493873E-05 AXIAL RECESSION RATE =    2.578178E-04

AGNATION POINT TEMPERATURE =   5167.9233

        DLTE        DLTIS        DLTC         DLTC1        DLTC2        DLTL         DLTS        DTH
   4.10973E-01 2.25729E-02 2.75906E-01 8.09733E-03 6.08438E-03 9.90000E+01 1.077[illegible]E+02 6.03637E-03


MCYC =        29 TIME =     15.2895     DTIME =     6.036370E-03
IAL RECESSION =    1.6[illegible]4225E-05 AXIAL RECESSION RATE =    2.578312E-04

AGNATION POINT TEMPERATURE =   5176.3079

        DLTE        DLTIS        DLTC         DLTC1        DLTC2        DLTL         DLTS        DTH
   4.04437E-01 2.257[illegible]E-02 2.87359E-01 7.85240E-03 7.04415E-03 9.90000E+01 1.07721E+02 6.97303E-03


MCYC =        30 TIME =     15.2954     DTIME =     6.973048E-03
IAL RECESSION =    1.907872E-05 AXIAL RECESSION RATE =    2.578485E-04

AGNATION POINT TEMPERATURE =   5186.6529

        DLTE        DLTIS        DLTC         DLTC1        DLTC2        DLTL         DLTS        DTH
   3.97400E-01 2.25729E-02 2.73452E-01 9.07089E-03 7.00157E-03 9.90000E+01 1.07711E+02 6.97305E-03


MCYC =        31 TIME =     15.3025     DTIME =     6.973048E-03
IAL RECESSION =    1.984657E-05 AXIAL RECESSION RATE =    2.579707E-04

AGNATION POINT TEMPERATURE =   5195.2960

        DLTE        DLTIS        DLTC         DLTC1        DLTC2        DLTL         DLTS        DTH
   3.90191E-01 2.25729E-02 2.84106E-01 9.07254E-03 8.04100E-03 9.90009E+01 1.07703E+02 7.96920E-03


MCYC =        32 TIME =     15.3095     DTIME =     7.969198E-03
```

```
AGNATION POINT TEMPERATURE =   5265.7771

         DLTE          DLTIS          DLTC          DLTC1          DLTC2          DLTL          DLTS          DTW
  3.82522E-01 2.25729E-02 2.71190E-01 1.03685E-02 8.13612E-03 9.90000E+01 1.07494E+02 7.96920E-03


IMCYC =          33 TIME =      15.3175      DTIME =     7.969198E-03
IAL RECESSION =    2.375045E-05 AXIAL RECESSION RATE =     2.579087E-04

AGNATION POINT TEMPERATURE =   5217.7094

         DLTE          DLTIS          DLTC          DLTC1          DLTC2          DLTL          DLTS          DTW
  3.74552E-01 2.25729E-02 2.83649E-01 1.03697E-02 9.44723E-03 9.90000E+01 1.07684E+02 9.36381E-03


IMCYC =          34 TIME =      15.3254      DTIME .     9.363808E-03
IAL RECESSION =    2.580525E-05 AXIAL RECESSION RATE =     2.579296E-04

AGNATION POINT TEMPERATURE =   5229.4553

         DLTE          DLTIS          DLTC          DLTC1          DLTC2          DLTL          DLTS          DTW
  3.65189E-01 2.25729E-02 2.68685E-01 1.21842E-02 9.67141E-03 9.90000E+01 1.07673E+02 9.61022E-03


IMCYC =          35 TIME =      15.3348      DTIME =     9.610224E-03
IAL RECESSION =    2.822137E-05 AXIAL RECESSION RATE =     2.579535E-04

AGNATION POINT TEMPERATURE =   5243.2958

         DLTE          DLTIS          DLTC          DLTC1          DLTC2          DLTL          DLTS          DTW
  3.55578E-01 2.25729E-02 2.77344E-01 1.25059E-02 1.11870E-02 9.90000E+01 1.07662E+02 1.11118E-02


IMCYC =          36 TIME =      15.3444      DTIME =     1.111182E-02
IAL RECESSION =    3.070059E-05 AXIAL RECESSION RATE =     2.579770E-04

AGNATION POINT TEMPERATURE =   5256.9911

         DLTE          DLTIS          DLTC          DLTC1          DLTC2          DLTL          DLTS          DTW
  3.44466E-01 2.25729E-02 2.66458E-01 1.44610E-02 1.18468E-02 9.90000E+01 1.07649E+02 1.18822E-02


IMCYC =          37 TIME =      15.3555      DTIME =     1.188222E-02
IAL RECESSION =    3.356746E-05 AXIAL RECESSION RATE =     2.580047E-04
```

```
TAGNATION POINT TEMPERATURE =   5272.6760

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
   3.32980E-01 2.25729E-02 2.73757E-01 1.09454E-02 1.42700E-02 9.90000E+01 1.07637E+02 1.39743E-02


INCYC =         38 TIME =      15.3670      DTIME =     1.387434E-02
XIAL RECESSION =     3.658027E-05 AXIAL RECESSION RATE =     2.580321E-04

TAGNATION POINT TEMPERATURE =   5269.1963

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
   3.19110E-01 2.25729E-02 2.63793E-01 1.60602E-02 1.53226E-02 9.90000E+01 1.07622E+02 1.51957E-02


INCYC =         39 TIME =      15.3809      DTIME =     1.519571E-02
XIAL RECESSION =     4.011073E-05 AXIAL RECESSION RATE =     2.580635E-04

TAGNATION POINT TEMPERATURE =   5308.4304

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
   3.03914E-01 2.25729E-02 2.70327E-01 1.97846E-02 1.84775E-02 9.90000E+01 1.07607E+02 1.78773E-02


INCYC =         40 TIME =      15.3961      DTIME =     1.787731E-02
XIAL RECESSION =     4.403269E-05 AXIAL RECESSION RATE =     2.580965E-04

TAGNATION POINT TEMPERATURE =   5329.4268

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
   2.86037E-01 2.25729E-02 2.41342E-01 2.32793E-02 2.00914E-02 9.90000E+01 1.07589E+02 1.90651E-02


INCYC =         41 TIME =      15.4100      DTIME =     1.906913E-02
XIAL RECESSION =     4.864705E-05 AXIAL RECESSION RATE =     2.581350E-04

TAGNATION POINT TEMPERATURE =   5351.9397

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
   2.66986E-01 2.25729E-02 2.45852E-01 2.08345E-02 2.71662E-02 9.90000E+01 1.07569E+02 2.42698E-02


INCYC =         42 TIME =      15.4330      DTIME =     2.426983E-02
XIAL RECESSION =     5.357066E-05 AXIAL RECESSION RATE =     2.581770E-04
```

```
       DLTE        DLTI3        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
 2.42598E-01 2.25729E-02 2.55214E-01 3.16161E-02 3.06678E-02 9.00000E+01 1.07547E+02 3.03372E-02


IMCYC =        43 TIME =     15.4573      DTIME =    3.033725E-02
XIAL RECESSION =    5.98376E-05 AXIAL RECESSION RATE =    2.582221E-04

TAGNATION POINT TEMPERATURE =   5405.1928

       DLTE        DLTI3        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
 2.12396E-01 2.25729E-02 2.61534E-01 3.95249E-02 3.17474E-02 9.00000E+01 1.07522E+02 3.03372E-02


IMCYC =        44 TIME =     15.4876      DTIME =    3.033725E-02
XIAL RECESSION =    6.74722E-05 AXIAL RECESSION RATE =    2.582739E-04

TAGNATION POINT TEMPERATURE =   5432.5548

       DLTE        DLTI3        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
 1.82023E-01 2.25729E-02 2.55929E-01 3.95251E-02 3.06336E-02 9.00000E+01 1.07146E+02 3.60047E-02


IMCYC =        45 TIME =     15.5180      DTIME =    3.600470E-02
XIAL RECESSION =    7.553560E-05 AXIAL RECESSION RATE =    2.591738E-04

TAGNATION POINT TEMPERATURE =   5462.6129

       DLTE        DLTI3        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
 1.45619E-01 2.25729E-02 2.56525E-01 4.74407E-02 4.77178E-02 9.00000E+01 1.06633E+02 3.60047E-02


IMCYC =        46 TIME =     15.5540      DTIME =    3.600470E-02
XIAL RECESSION =    8.501579E-05 AXIAL RECESSION RATE =    2.604111E-04

TAGNATION POINT TEMPERATURE =   5490.2172

       DLTE        DLTI3        DLTC        DLTC1        DLTC2        DLTL         DLTS         DTH
 1.09210E-01 2.25729E-02 2.52291E-01 4.74314E-02 4.77666E-02 9.00000E+01 1.05176E+02 3.60047E-02


IMCYC =        47 TIME =     15.5900      DTIME =    3.600470E-02
XIAL RECESSION =    9.456456E-05 AXIAL RECESSION RATE =    2.615213E-04

TAGNATION POINT TEMPERATURE =   5521.6254
```

DLTE	DLTI3	DLTC	DLTC1	DLTC2	DLTL	DLTS	DTM
7.28094E-02	2.25729E-02	2.50808E-01	4.74442E-02	5.33247E-02	9.00000E+01	1.05788E+02	3.64047E-02

TIMCYC = 48 TIME = 15.6272 DTIME = 3.640470E-02
AXIAL RECESSION = 1.003915E-04 AXIAL RECESSION RATE = 2.624640E-04

STAGNATION POINT TEMPERATURE = 5541.4062

DLTE	DLTI3	DLTC	DLTC1	DLTC2	DLTL	DLTS	DTM
3.64047E-02	2.25729E-02	2.48410E-01	4.74044E-02	5.23735E-02	9.00000E+01	1.05360E+02	3.64047E-02

TIMCYC = 49 TIME = 15.6636 DTIME = 3.640470E-02
AXIAL RECESSION = 1.136851E-04 AXIAL RECESSION RAT. = 2.635240E-04

STAGNATION POINT TEMPERATURE = 5569.2302

BODY POINT LOCATIONS AND SURFACE ENERGY BALANCE RESULTS AT
TIME = 15.7000 SEC

• DENOTES ANGLE LIMIT

POINT NUMBER	Z (INCHES)	S (INCHES)	WALL TEMPERATURE (DEG R)	S-DOT TOTAL (IN/SEC)	S-DOT EROSION (IN/SEC)	PARTICLE ROUGHNESS (MILS)	B-PRIME THERMO-CHEM	CHM	CH (LBM/FT**2-SEC)	CHZ
1	.00143	0.00300	5569.23	0.	0.	0.	0.	0.	0.	0.00000
2	.00074	.07025	5559.81	31.5660E-04	0.	0.	18.4968E-02	16.3974E+02	16.5390E-02	.18711
3	.01596	.13671	5499.39	30.7010E-04	0.	0.	18.3420E-02	16.1644E+02	16.3196E-02	.18335
4	.03735	.22929	5351.50	28.8158E-04	0.	0.	18.0208E-02	15.4117E+02	15.5905E-02	.17482
5	.07104	.31755	5009.15	26.4974E-04	0.	0.	17.9630E-02	14.1726E+02	14.3923E-02	.16123
6	.12360	.41045	4719.55	23.2576E-04	0.	0.	17.7074E-02	12.4191E+02	12.6430E-02	.14191
7	.19765	.50664	4056.95	18.5790E-04	0.	0.	17.8101E-02	99.0932E+01	10.1709E-02	.11392
8	.30200	.60370	3136.80	13.3143E-04	0.	0.	17.6705E-02	70.9400E+01	73.2475E-03	.08220
9	.45063	.68729	1957.56	71.1461E-05	0.	0.	17.5054E-02	37.7025E+01	39.6264E-03	.04430
10	.68192	.70714	1160.27	31.9076E-05	0.	0.	15.2806E-02	19.1056E+01	20.3591E-03	.02247
11	.95584	.78661	857.23	19.8027E-05	0.	0.	14.2474E-02	12.6630E+01	13.5515E-03	.01486
12	1.19008	.81669	787.36	17.6359E-05	0.	0.	14.0235E-02	11.0361E+01	12.2615E-03	.01343
13	1.41703	.83746	767.29	16.1896E-05	0.	0.	13.9566E-02	10.5321E+01	11.3103E-03	.01238
14	1.61421	.86167	754.49	15.1150E-05	0.	0.	13.9133E-02	98.5070E+00	10.5921E-03	.01159
15	1.79440	.88360	746.43	14.2923E-05	0.	0.	13.8850E-02	93.2331E+00	10.0360E-03	.01098
16	1.96692	.90025	738.78	13.6374E-05	0.	0.	13.8584E-02	89.0497E+00	95.9451E-04	.01050
17	2.11675	.92339	732.34	13.1046E-05	0.	0.	13.8358E-02	85.6425E+00	92.3075E-04	.01010
18	2.26669	.94155	727.08	12.6590E-05	0.	0.	13.8172E-02	82.7896E+00	89.3339E-04	.00977
19	2.40757	.95915	722.69	12.2772E-05	0.	0.	13.8015E-02	80.3275E+00	86.7316E-04	.00949
20	2.54839	.97639	718.91	11.9361E-05	0.	0.	13.7870E-02	78.1291E+00	84.4057E-04	.00923
21	2.69071	.99387	716.10	11.6209E-05	0.	0.	13.7773E-02	76.0210E+00	82.2394E-04	.00899
22	2.83067	1.01208	719.82	11.3151E-05	0.	0.	13.7719E-02	74.0883E+00	80.1077E-04	.00876
23	3.00004	1.03184	717.08	11.3838E-05	0.	0.	13.7787E-02	74.4377E+00	80.5533E-04	.00881

*** OVERLAY(3,0) //ENVIRT ***

*** OVERLAY(3,1) //VORTI ***

SHOULDER POINT = 22 SONIC POINT = 8

*** CVERLAY(3,2) //VORT15 *** -

NEW CURVE FIT OVER 1- ONLY POINTS
9CURVES FIT TO, 71 POINTS

CURVE	A	B	C	AUC(I+1)
1	-97.71055E+03	1[illegible].20242E+04	-20.91601E-15	11.40459E-03
2	74.84497E+02	15.06249E+04	13.64202E+00	22.72231E-03
3	55.24510E+03	15.74543E+04	38.34211E+00	34.27110E-03
4	-31.03079E+04	17.25121E+04	-39.10044E+01	45.46638E-03
5	-14.08207E+05	28.21300E+04	-26.60792E+02	59.25125E-03
6	23.12102E+05	-15.85206E+05	10.40027E+03	71.82920E-03
7	-36.14239E+05	69.28537E+04	-20.17649E+03	90.14291E-03
8	-20.95204E+03	16.28887E+03	11.67040E+03	28.68557E-02
9	-11.80576E+05	66.96960E+04	-82.03200E+03	29.25928E-02

*** OVERLAY(3,3) //VORT3 *** -

****
* VORT CALLED AT INTERMEDIATE OUTPUT TIME *
****

TABLE-1 SUMMARY INFORMATION

ITERATION NO. ITR	ITERATION NO. ITS	TIMEP (SEC)	ALTITUDE ALT (FT)	FREESTREAM MACH-NO. M-INF	STAGNATION PT. PRESSURE PT2 (ATM)	STAGNATION PT. ENTHALPY -HO- (BTU/LBM)
75	782	30.6173	8584	12.541	151.7465	3814.5

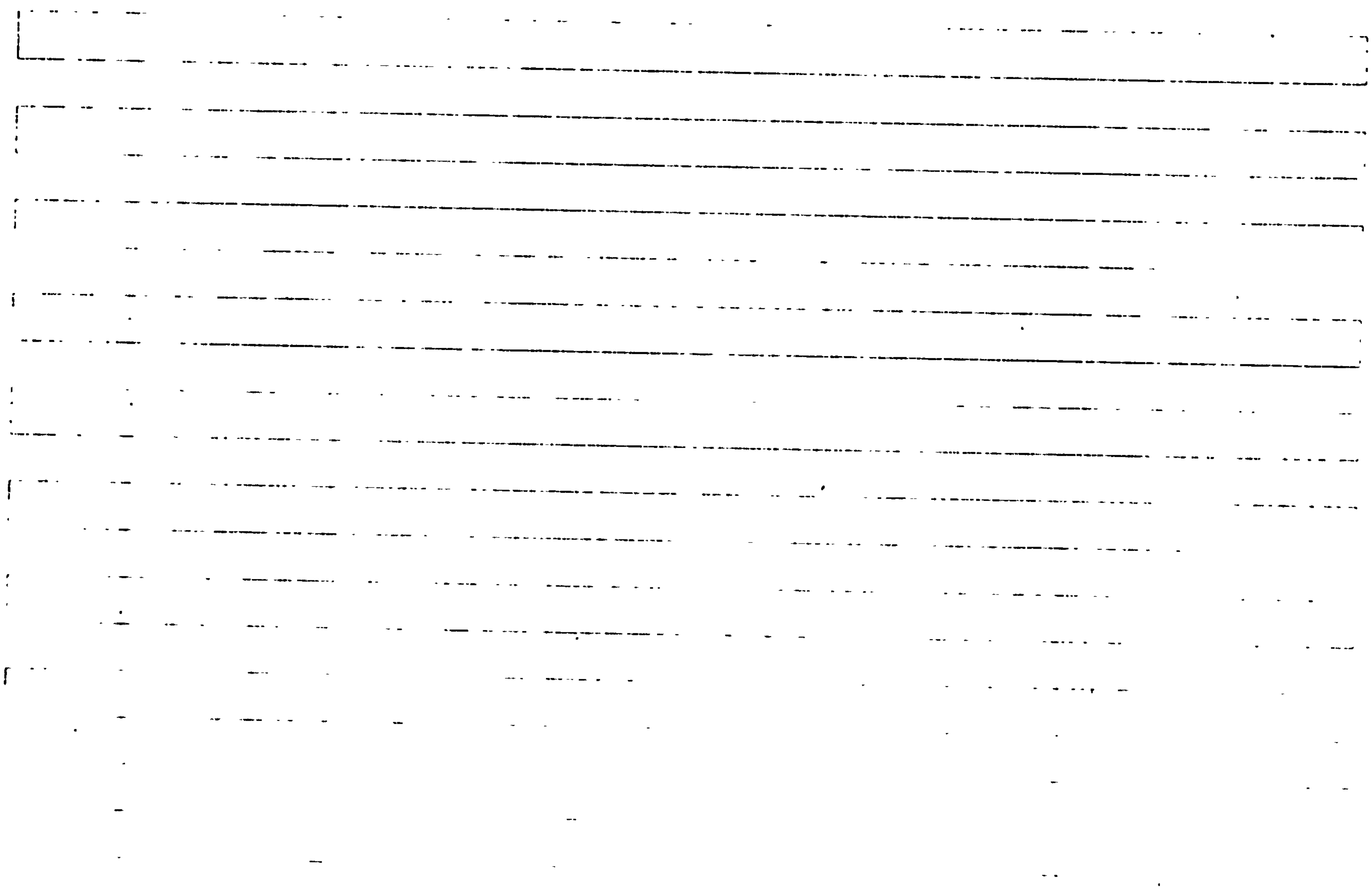
STAG. PT. RECESSION SPREC (INCH)	CURRENT NOSE RADIUS RN (INCH)	EFFECTIVE NOSE RADIUS R-EFF (INCH)	STAGNATION PT. HEAT TRANS. COEF. SBHTC (LBM/FT**2-SEC)	TRANSITION STREAM LENGTH S-TRAN (INCH)	SONIC PT. AXIAL LENGTH X-STAR (INCH)	SONIC PT. RADIAL LENGTH Y-STAR (INCH)
1.7781	.0391	.0451	8.4981	.0199	1.7986	.0350

TABLE-2 SUMMARY DISTRIBUTION TABLE

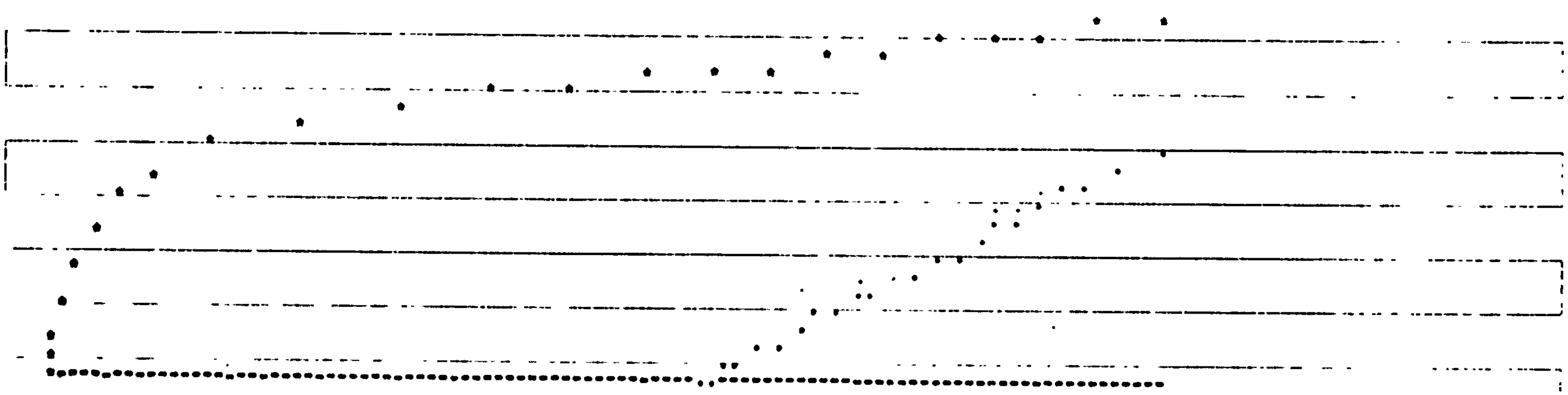
J = ACTUAL SURFACE POINT INDEX, I = INTEGRATION POINT INDEX, LAM = TRANSITION FLAG

J	I	LAM	STREAM LENGTH S (INCH)	AXIAL LENGTH X (INCH)	RADIAL LENGTH Y (INCH)	BODY ANGLE (DEG)	PRESSURE RATIO PE/PT2	EDGE MACH ME	ROUGHNESS HEIGHT K MIL	LAMINAR CHO CHO-LAM (LBM/FT2-SEC)	TURBULENT CHO CHO-TURB (LBM/FT2-SEC)	HEATING AUG. PARAMETER FXR	MOMENTUM THICKNESS THETA (MIL)	MOMENTUM THICKNESS REYNOLDS NO. RE-THETA
		-1	0.0000	1.7781	0.0000	90.00	1.000000	0.0000	.40000	9.74167	9.74167	1.1443	.034	0.00
1	2	0	.0306	1.7495	.0284	52.57	.667143	.9279	1.00000	7.09742	14.43206	1.5136	.111	191.64
2	29	0	.0791	1.8282	.0576	35.21	.343905	1.8403	1.00000	3.03334	10.09210	1.6554	.288	597.63
3	34	-1	.1332	1.8735	.0872	31.94	.284988	2.3467	1.00000	2.18750	8.59074	1.4782	.384	1012.84
4	36	-1	.1912	1.9234	.1168	29.71	.252638	2.7004	1.00000	1.75998	8.63557	1.4686	.496	1400.27
5	38	-1	.2521	1.9768	.1460	28.45	.231293	2.9387	.99406	1.50626	7.90710	1.6557	.598	1593.45
6	40	-1	.3134	2.0309	.1750	28.20	.227013	3.1808	.98657	1.37485	7.95572	1.4589	.638	2344.17
7	42	-1	.3741	2.0842	.2039	28.46	.230781	3.4330	.99435	1.31001	8.84704	1.6850	.438	2833.41
8	44	-1	.4423	2.1473	.2249	22.18	.149108	3.8482	.91239	.95329	5.22534	1.5213	.387	3356.44
9	46	-1	.5053	2.2044	.2564	24.92	.181503	3.7963	.88836	.07438	6.20531	1.5743	.833	3712.35
10	50	-1	.5545	2.2402	.2902	43.37	.474053	3.4029	1.00000	1.96020	17.59252	1.8496	.880	4283.52
11	54	-1	.6148	2.2937	.3179	26.46	.202338	3.9902	.93437	1.12841	7.09151	1.6327	.921	5184.73
12	56	-1	.6761	2.3491	.3444	25.54	.189741	4.0718	.90679	.94843	6.52666	1.6056	1.015	5650.23
13	58	-1	.7346	2.4000	.3731	29.37	.244174	3.9748	1.00000	1.07318	8.81444	1.7129	.912	6124.02
14	61	-1	.8027	2.4654	.3919	16.08	.081094	4.7805	.62326	.59380	2.60329	1.3182	1.797	6631.43
15	63	-1	.8661	2.5251	.4133	14.72	.118117	4.5325	.73253	.56643	3.54927	1.3962	1.467	6800.48
16	69	-1	.9236	2.5644	.4530	44.14	.487524	3.7139	1.00000	1.83906	17.16540	1.8653	.652	7367.02
17	72	-1	.9863	2.6162	.4915	32.29	.286657	4.0426	1.00000	1.27862	9.96963	1.7410	1.001	8423.30
18	74	-1	1.0549	2.6774	.5222	26.07	.196961	4.3196	.92268	.87939	6.44379	1.6116	1.348	9129.83
19	76	-1	1.1284	2.7438	.5539	25.48	.188932	4.3563	.93500	.77139	6.10631	1.5957	1.455	9673.08
20	78	-1	1.2122	2.8129	.6015	34.63	.326199	3.9948	1.00000	1.14027	10.48907	1.7469	1.145	10412.82
21	81	-1	1.3089	2.8467	.6495	23.22	.159464	4.5356	.83730	.71150	5.10084	1.5577	1.808	11328.83
22														

23 84 -1 1.4164 3.0000 .6799 8.63 .044173 5.4120 .40009 .23417 1.00995 ---TIME=---30.61 SEC- 1.0000 4.053 FPA PAGE125 11632.67



* * * CURRENT SHAPE ON NOSE * * *



*** OVERLAY(1,0) //THERM

DLTE	DLTIS	DLTC	DLTC1	DLTC2	DLTL	DLTS	DTW
8.76895E-02	0.	1.88614E-01	1.01062E-02	2.07474E-02	9.00000E+01	1.36993E-01	9.74328E-03

TIMCYC = 782 TIME = 30.6123 DTIME = 9.743276E-03
AXIAL RECESSION = .148172 AXIAL RECESSION RATE = 4.166164E-02

STAGNATION POINT TEMPERATURE = 7870.1922

NSTEP =782 TIME =30.6123E+00 DTIME =97.4328E-04

DLTS =13.3842E-02 DLTC =17.8423E-02

DS

1.0142E-01	1.0050E-01	9.7371E-02	9.3780E-02	8.9914E-02	8.5821E-02	8.1749E-02	7.7980E-02	7.3434E-02	6.9211E-02
6.7530E-02	6.4355E-02	6.1188E-02	5.8771E-02	5.5202E-02	5.2091E-02	5.1894E-02	5.1822E-02	5.0994E-02	5.0717E-02
5.2067E-02	5.4774E-02	5.6550E-02							

SDOT

4.1705E-02	3.2124E-02	2.4962E-02	2.3649E-02	2.1024E-02	1.9016E-02	1.8087E-02	2.0282E-02	1.1129E-02	1.3751E-02
4.5262E-02	1.6387E-02	1.4845E-02	2.0991E-02	4.3375E-03	6.8274E-03	8.3210E-02	2.4014E-02	1.8097E-02	1.3555E-02
2.5231E-02	1.1647E-02	1.6716E-03							

SW

0.	1.7635E+03	2.2196E+03	2.6651E+03	2.9524E+03	3.2159E+03	3.3154E+03	3.5307E+03	3.9961E+03	4.0152E+03
3.7816E+03	3.6022E+03	3.5873E+03	3.7485E+03	3.7075E+03	4.4188E+03	4.7082E+03	3.4308E+03	3.4747E+03	3.7126E+03
4.4868E+03	2.9828E+03	8.8886E+02							

4.0084E+03 2.7425E+03 4.4405E+02

T-DIST. IN L=1 PLANE

7.8702E+03	5.1957E+03	3.8440E+03	3.1627E+03	2.8916E+03	2.5158E+03	2.9578E+03	2.1923E+03	2.5084E+03	2.5219E+03
7.8051E+03	5.1593E+03	3.8220E+03	3.1531E+03	2.8662E+03	2.5850E+03	2.7913E+03	2.3591E+03	2.5103E+03	2.5235E+03
7.5845E+03	5.0357E+03	3.7356E+03	3.1206E+03	2.7804E+03	2.8232E+03	2.2273E+03	2.9245E+03	2.5147E+03	2.5235E+03
7.5206E+03	4.8935E+03	3.6353E+03	3.0592E+03	2.8283E+03	2.4935E+03	3.0179E+03	2.0339E+03	2.[illegible]31E+03	2.5235E+03
7.4624E+03	4.7752E+03	3.5450E+03	3.0163E+03	2.7489E+03	2.8008E+03	2.1041E+03	3.1379E+03	2.[illegible]71E+03	2.5235E+03
7.4163E+03	4.6603E+03	3.4628E+03	2.9746E+03	2.7692E+03	2.5125E+03	3.0152E+03	1.8689E+03	[illegible]9E+03	2.5235E+03
7.4066E+03	4.5461E+03	3.3920E+03	2.9417E+03	2.7321E+03	2.7341E+03	2.1284E+03	3.2490E+03	[illegible]45E+03	2.5235E+03
7.4129E+03	4.4860E+03	3.3433E+03	2.9202E+03	2.7327E+03	2.5550E+03	2.9634E+03	1.7896E+03	[illegible]86E+03	2.5235E+03
7.1668E+03	4.3254E+03	3.2536E+03	2.8931E+03	2.7161E+03	2.6748E+03	2.2292E+03	3.2770E+03	2.[illegible]001E+03	2.5235E+03
7.2605E+03	4.0642E+03	3.2113E+03	2.8745E+03	2.7106E+03	2.5835E+03	2.8622E+03	1.7856E+03	2.6384E+03	2.5235E+03
7.6875E+03	4.2378E+03	3.2745E+03	2.8896E+03	2.7128E+03	2.6542E+03	2.3146E+03	3.2302E+03	2.376[illegible]E+03	2.5235E+03
7.3346E+03	4.3737E+03	3.2970E+03	2.8951E+03	2.7204E+03	2.6047E+03	2.7819E+03	1.8643E+03	2.6622E+03	2.5235E+03
7.2094E+03	4.3287E+03	3.2374E+03	2.6661E+03	2.7185E+03	2.6462E+03	2.4087E+03	3.1250E+03	2.3616E+03	2.5235E+03
7.4187E+03	4.2947E+03	3.2461E+03	2.8836E+03	2.7243E+03	2.6220E+03	2.7053E+03	1.9556E+03	2.4780E+03	2.5235E+03
6.6504E+03	4.0797E+03	3.1747E+03	2.8713E+03	2.7216E+03	2.6449E+03	2.4835E+03	2.9892E+03	2.3644E+03	2.5235E+03
6.8729E+03	3.7241E+03	3.1074E+03	2.8572E+03	2.7232E+03	2.6280E+03	2.6599E+03	2.1457E+03	2.6717E+03	2.5235E+03
7.6696E+03	3.9215E+03	3.1985E+03	2.8765E+03	2.7406E+03	2.6611E+03	2.5187E+03	2.8611E+03	2.4001E+03	2.5235E+03
7.4771E+03	4.3132E+03	3.3229E+03	2.9525E+03	2.7737E+03	2.6586E+03	2.6593E+03	2.2993E+03	2.6359E+03	2.5235E+03
7.2657E+03	4.3097E+03	3.3360E+03	2.9746E+03	2.7914E+03	2.6864E+03	2.5647E+03	2.7415E+03	2.4488E+03	2.5235E+03
7.2700E+03	4.2793E+03	3.3651E+03	3.0056E+03	2.8155E+03	2.6936E+03	2.6498E+03	2.4400E+03	2.5945E+03	2.5235E+03
7.5083E+03	4.2951E+03	3.4354E+03	3.1[illegible]59E+03	2.8496E+03	2.7242E+03	2.6124E+03	2.6380E+03	2.5051E+03	2.5235E+03
7.2375E+03	4.8457E+03	3.7370E+03	3.2035E+03	2.9264E+03	2.7595E+03	2.6570E+03	2.5677E+03	2.5460E+03	2.5235E+03
6.5128E+03	5.2869E+03	3.9921E+03	3.3214E+03	2.9829E+03	2.7852E+03	2.6812E+03	2.5437E+03	2.5617E+03	2.5219E+03

DLTE	DLTIS	DLTC	DLTC1	DLTC2	DLTL	DLTS	DTM
7.79462E-02	0.	1.78423E-01	1.44987E-02	1.00020E-03	9.90000E+01	1.33442E-01	9.99310E-04

TIMCYC = 743 TIME = 30.6221 DTIME = 9.993104E-04
AXIAL RECESSION = .148578 AXIAL RECESSION RATE = 4.176539E-02

STAGNATION POINT TEMPERATURE = 7870.1080

DLTE	DLTIS	DLTC	DLTC1	DLTC2	DLTL	DLTS	DTM
7.69460E-02	0.	1.89371E-01	1.29758E-03	1.60672E-03	9.90000E+01	1.33441E-01	1.28245E-03

TIMCYC = 744 TIME = 30.6231 DTIME = 1.282448E-03
AXIAL RECESSION = .148619 AXIAL RECESSION RATE = 4.088696E-02

STAGNATION POINT TEMPERATURE = 7870.1080

DLTE	DLTIS	DLTC	DLTC1	DLTC2	DLTL	DLTS	DTM
7.56645E-02	0.	2.04730E-01	1.66686E-03	8.39[illegible]E-03	9.90003E+01	1.33327E-01	1.64488E-03

TIMCYC = 745 TIME = 30.6243 DTIME = 1.644879E-03
AXIAL RECESSION = .148672 AXIAL RECESSION RATE = 4.098726E-02

STAGNATION POINT TEMPERATURE = 7870.1224

```
STAGNATION POINT TEMPERATURE =   7870.1224

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
    7.80194E-02 0.           2.02977E-01 2.13780E-03 3.44678E-02 9.90000E+01 1.33148E-01 2.11484E-03

TIMCYC =      746 TIME =     30.6260     DTIME =    2.114845E-03
AXIAL RECESSION =     .148739     AXIAL RECESSION RATE =    4.099350E-02
STAGNATION POINT TEMPERATURE =   7870.1452

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
    7.19047E-02 0.           2.03932E-01 2.74846E-03 4.01114E-02 9.90000E+01 1.32995E-01 2.66314E-03

TIMCYC =      747 TIME =     30.6281     DTIME =    2.663134E-03
AXIAL RECESSION =     .148826     AXIAL RECESSION RATE =    4.090163E-02
STAGNATION POINT TEMPERATURE =   7870.1552

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
    6.92414E-02 0.           1.92511E-01 3.46063E-03 3.75212E-02 9.90000E+01 1.32772E-01 3.29722E-03

TIMCYC =      748 TIME =     30.6308     DTIME =    3.297218E-03
AXIAL RECESSION =     .148934     AXIAL RECESSION RATE =    4.091132E-02
STAGNATION POINT TEMPERATURE =   7870.1934

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
    6.59234E-02 0.           1.86704E-01 4.28509E-03 4.58519E-02 9.90000E+01 1.32462E-01 4.12152E-03

TIMCYC =      749 TIME =     30.6341     DTIME =    4.121523E-03
AXIAL RECESSION =     .149069     AXIAL RECESSION RATE =    4.092490E-02
STAGNATION POINT TEMPERATURE =   7870.2051

        DLTE        DLTIS        DLTC        DLTC1        DLTC2        DLTL        DLTS        DTH
    6.18228E-02 0.           1.70746E-01 5.35448E-03 4.00317E-02 9.90000E+01 1.32117E-01 5.15190E-03

TIMCYC =      750 TIME =     30.6382     DTIME =    5.151904E-03
AXIAL RECESSION =     .149238     AXIAL RECESSION RATE =    4.094024E-02
STAGNATION POINT TEMPERATURE =   7870.2612
```

```
     DLTE          DLTIS       DLTC        DLTC1       DLTC2       DLTL        DLTS        DTH
 5.66709E-02 0.            1.55060E-01 6.69521E-03 5.15971E-02 9.90000E+01 1.31611E-01 6.29677E-03

 TIMCYC =        751 TIME =     30.6433     DTIME =     6.296771E-03
 AXIAL RECESSION =     .149449     AXIAL RECESSION RATE =    4.096178E-02

 STAGNATION POINT TEMPERATURE =   7870.2847

     DLTE          DLTIS       DLTC        DLTC1       DLTC2       DLTL        DLTS        DTH
 5.03742E-02 0.            1.21096E-01 8.17755E-03 4.18805E-02 9.90000E+01 1.31088E-01 7.19631E-03

 TIMCYC =        752 TIME =     30.6496     DTIME =     7.196310E-03
 AXIAL RECESSION =     .149707     AXIAL RECESSION RATE =    4.098698E-02

 STAGNATION POINT TEMPERATURE =   7870.3505

     DLTE          DLTIS       DLTC        DLTC1       DLTC2       DLTL        DLTS        DTH
 4.31770E-02 0.            1.00054E-01 9.35204E-03 5.36881E-02 9.90000E+01 1.30357E-01 8.63557E-03

 TIMCYC =        753 TIME =     30.6568     DTIME =     8.635572E-03
 AXIAL RECESSION =     .150002     AXIAL RECESSION RATE =    4.102042E-02

 STAGNATION POINT TEMPERATURE =   7870.4309
```

BODY POINT LOCATIONS AND SURFACE ENERGY BALANCE RESULTS AT
TIME = 30.4655 SEC

* DENOTES ANGLE LIMIT

POINT NUMBER	Z (INCHES)	R (INCHES)	WALL TEMPERATURE (DEG R)	S-DOT TOTAL (IN/SEC)	S-DOT EROSION (IN/SEC)	PARTICLE ROUGHNESS (MILS)	B-PRIME THERMO-CHEM	CHH	CM (LBM/FT**2-SEC)	CMZ
1	1.80428	0.00000	7870.40	0.	0.	0.	0.	0.	0.	0.00000
2	1.81564	.02778	7835.15	38.5561E-02	0.	0.	38.4041E-02	35.7339E+03	97.8860E-01	12.23183
3	1.85410	.05634	7584.00	29.9421E-02	0.	0.	36.9665E-02	28.4695E+03	78.9732E-01	9.79910
4	1.89461	.08524	7520.31	28.4225E-02	0.	0.	34.2696E-02	27.4408E+03	76.4054E-01	9.48779
5	1.94570	.11434	7453.83	25.2534E-02	0.	0.	35.4764E-02	24.8629E+03	69.0317E-01	8.55184
6	1.99493	.14313	7418.57	22.8624E-02	0.	0.	34.6011E-02	22.9816E+03	64.3491E-01	7.89273
7	2.05424	.17150	7404.29	22.7197E-02	0.	0.	34.3096E-02	23.0409E+03	60.6209E-01	7.31287
8	2.10295	.19972	7413.68	24.3307E-02	0.	0.	34.0867E-02	20.0971E+03	69.7871E-01	8.43053
9	2.15832	.22691	7191.70	13.6018E-02	0.	0.	30.7711E-02	15.2901E+03	43.2882E-01	5.20569
10	2.21895	.25174	7252.98	16.3876E-02	0.	0.	31.1243E-02	18.1659E+03	51.3357E-01	4.18475
11	2.26926	.27712	7474.65	53.7328E-02	0.	0.	37.0994E-02	50.6883E+03	14.1305E+00	17.55001
12	2.30547	.31264	7340.04	19.8035E-02	0.	0.	33.3381E-02	20.5103E+03	58.0924E-01	7.07659
13	2.35033	.33894	7297.60	17.7843E-02	0.	0.	32.2439E-02	18.9357E+03	53.7768E-01	6.51627
14	2.41223	.36547	7414.45	25.0977E-02	0.	0.	33.9730E-02	25.4132E+03	72.0296E-01	8.80499
15	2.46809	.38993	6754.84	55.2097E-03	0.	0.	29.0224E-02	77.7235E+02	22.4080E-01	2.59502
16	2.53127	.40791	6906.62	78.6116E-03	0.	0.	25.0027E-02	10.6376E+03	30.5053E-01	3.56418
17	2.58609	.43376	7660.98	51.4475E-02	0.	0.	34.1386E-02	49.2201E+03	13.5760E+00	17.14872
18	2.62493	.48028	7470.07	26.6485E-02	0.	0.	34.3390E-02	28.5931E+03	81.3429E-01	9.96196
19	2.68240	.51416	7299.56	17.4546E-02	0.	0.	31.9758E-02	18.6001E+03	53.2222E-01	6.84021
20	2.74748	.54595	7274.33	16.3286E-02	0.	0.	31.4905E-02	17.6490E+03	50.5562E-01	6.10235
21	2.81839	.58357	7507.57	30.2594E-02	0.	0.	34.0928E-02	30.0526E+03	85.5337E-01	10.48328
22	2.89778	.64267	7236.86	13.9677E-02	0.	0.	31.7203E-02	14.9079E+03	42.9332E-01	5.18836
23	3.00004	.67772	6509.23	20.0160E-03	0.	0.	22.2091E-02	30.0212E+02	87.8719E-02	1.00917

```
*************************************************************************
*   RR    EEEE  SS   TTTTT   A    RR    TTTTT    OOO   PP   TTTTT III  OOO  NN   N  *
*   R R   E    S  S    T    A A   R R     T     O   O  P P    T    I  O   O N N  N  *
*   R  R  E    S       T   A   A  R  R    T     O   O  P  P   T    I  O   O N  N N  *
*   R R   EEE   S      T   AAAAA  R R     T     O   O  P P    T    I  O   O N   NN  *
*   RR    E      S     T   A   A  RR      T     O   O  PP     T    I  O   O N    N  *
*   RR    E       S    T   A   A  RR      T     O   O  P      T    I  O   O N    N  *
*   R R   E    S  S    T   A   A  R R     T     O   O  P      T    I  O   O N    N  *
*   R  R  EEEE  SS     T   A   A  R  R    T      OOO   P      T   III  OOO  N   NN  *
*                                                                                   *
*                        RESTART DATA FILE WRITTEN AT -                             *
*                                                                                   *
*                 FILE DUMP STEP              IRESRT=   15                          *
*                 ITERATION NUMBER                NT=   75                          *
*                 TRAJECTORY TIME              TIMEP=,  3.0465457E+01               *
*                 PROJECTILE ALTITUDE         ALTINE=  8.5835098E+03                *
*************************************************************************

*** OVERLAY(3,0) //ENVIRT *** * * * * * * * * * * * * * * * * * * * * * * * * * *

*** OVERLAY(3,1) //VORT1  *** * * * * * * * * * * * * * * * * * * * * * * * * * *

        SHOULDER POINT = 22     SONIC POINT =  3

*** OVERLAY(3,2) //VORT15 *** * * * * * * * * * * * * * * * * * * * * * * * * * *
```

NEW CURVE FIT DONE TO ADDY POINTS
4CURVES FIT TO, 12 POINTS

CURVE	A	B	C	AUC(I+1)
1	-29.06533E+05	15.78114E+05	23.49963E-17	29.58942E-05
2	-70.70283E+06	16.19535E+05	-59.35792E-01	71.90735E-05
3	11.60393E+07	13.49973E+05	90.62234E+00	10.18746E-04
4	50.01652E+06	14.84794E+05	22.10096E+00	14.02973E-04

*** OVERLAY(3,3) //VORT3 ***

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APPENDIX A

DESCRIPTION OF UNLABELLED OUTPUT VARIABLES

Name		Description	Units
BPRIM	-	Nondimensional ablation rate $$B' = \frac{\dot{m}}{\rho_e u_e C_M}$$	--
CH	-	Blown heat transfer coefficient (i.e. effect of mass addition accounted for)	lb/ft^2-sec
CHZ	-	Non-blow heat transfer coefficient	lb/ft^2-sec
CM	-	Mass transfer coefficient	lb/ft^2-sec
DLTC	-	Explicit finite-difference stability limit time step $$DLTC = \frac{d^2}{4\alpha}$$	sec
DLTC1	-	Surface heat flux rise control time step $$DLTC1 = \Delta t_{old} \left(\frac{q_{old}}{q_{new}}\right) CTF$$	sec
DLTC2	-	Surface temperature rise control time step $$DLTC2 = \Delta t_{old} \frac{STRD}{STRM}$$	sec
DLTE	-	Time to next specified environment call	sec
DLTIS	-	Conduction time step for first calculation step $$DLTIS = STRD \left(\frac{\rho_m C_p}{\dot{q}}\right) \frac{\delta}{2}$$	sec
DLTS	-	Surface recession control time step $$DLTS = \frac{\delta}{\dot{S}_{max}}$$ where δ is the distance between the surface and the adjacent in-depth nodes	sec
DTH	-	Conduction time step finally chosen from all of the above limits	sec
HCH	-	Sensible enthalpy of the solid material	Btu/lb
HE	-	Entholpy of boundary layer edge gases at the wall temperature, h_{ew}	Btu/lb
HFO	-	Heat of formation	Btu/lb

Name		Description	Units
HZ	-	Summation $\sum z^{*}_{ie} h_i^{T_w}$	Btu/lb
HZW	-	Summation $\sum z^{*}_{iw} h_i^{T_w}$	Btu/lb
RHO	-	Material density	lb/ft^3
RIOUT	-	Radial distance from the body centerline to the material interface boundary	in
ROUT	-	Initial surface point radius	in
SLOP	-	Initial body angle slope with respect to the centerline	deg
STRM	-	Maximum surface temperature rise during the previous time step	°R
TBRPL	-	Laminar blowing rate reduction parameter λ in Equation (2-61)	--
TBRPT	-	Turbulent blowing rate reduction parameter λ in Equation (2-61)	--
T-DIST	-	Explicit grid temperature array	°R
TT-DIST	-	Implicit grid temperature array	°R
TCHEM	-	Ablation parameter defined by Equation (3-3) or (3-5)	Btu/lb
TEMP	-	Temperature	°R
TFO	-	Datum temperature for the heat of formation	°R
TSEN	-	Enthalpy of wall gases, h_w	Btu/lb
ZOUT	-	Initial surface point axial coordinate	in